THE WORLD WAR II ORDNANCE DEPARTMENT'S GOVERNMENT-OWNED CONTRACTOR-OPERATED (GOCO) INDUSTRIAL FACILITIES: RADFORD ORDNANCE WORKS HISTORIC INVESTIGATION

by
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Gray & Pape, Inc.

U.S. ARMY MATERIEL COMMAND HISTORIC CONTEXT SERIES
REPORT OF INVESTIGATIONS
NUMBER 6A

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This report presents the results of an examination of historical records related to the construction and operations of the Radford Army Ammunition Plant (RAAP) near Radford, Virginia. This project was undertaken as part of a larger Legacy Resource Program demonstration project to assist small installations and to aid in the completion of mitigation efforts set up in a 1993 Programmatic Agreement among the Army Materiel Command, the Advisory Council on Historic Preservation, and Multiple State Historic Preservation Officers concerning a program to cease maintenance, excess, and dispose of particular properties. As part of the larger project to develop the national historic context of seven sample installations on a state and local level, the major focus of the project at RAAP was to document the impacts that the facility had on the state and local environments.

The project was conducted by Gray & Pape, Inc., under subcontract to Geo-Marine, Inc., during early 1995. Duane Peter, Senior Archeologist at Geo-Marine, Inc., served as Principal Investigator. Ashley M. Neville and Debra A. McClane conducted the oral history interviews as well as the archival and historic investigations.

As one of the Ordnance Department's Government-Owned Contractor-Operated industrial facilities, RAAP was designed to provide munitions and materiel for European and American forces during World War II. The facility initially was two units: Radford Ordnance Works, near Radford, Virginia and the New River Ordnance Plant near Dublin, Virginia. In addition to the technical aspects of munitions production, this report discusses the direct and indirect effects construction and operations had on Radford and the surrounding small communities.

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RADFORD ORDNANCE WORKS HISTORIC INVESTIGATION

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MANAGEMENT SUMMARY

This report presents the results of an examination of historical records related to the construction and operations of the Radford Army Ammunition Plant (RAAP) near Radford, Virginia. This project was undertaken as part of a larger Legacy Resource Program demonstration project to assist small installations and to aid in the completion of mitigation efforts set up in a 1993 Programmatic Agreement among the Army Materiel Command, the Advisory Council on Historic Preservation, and Multiple State Historic Preservation Officers concerning a program to cease maintenance, excess, and dispose of particular properties. As part of the larger project to develop the national historic context of seven sample installations on a state and local level, the major focus of the project at RAAP was to document the impacts that the facility had on the state and local environments.

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We would like to thank Joseph Murphey of the U.S. Army Corps of Engineers, Fort Worth District, who was most supportive of our efforts. He provided constructive criticism and management direction throughout this project. In the Geo-Marine, Inc., office in Plano, the final editing and overall production of the report were the responsibilities of Ms. Sharlene Allday. Ms. Sandy Carr provided computer graphics, and Ms. Denise Pemberton generated the computerized format for the layout and design of the book.

CHAPTER 1
INTRODUCTION

This report presents the results of research into the historical record of Radford Army Ammunition Plant, 1940-1995, originally built as two units—the Radford Ordnance Works (ROW) near Radford, Virginia, and the nearby New River Ordnance Plant (NROP) near Dublin, Virginia—and touches briefly on the now-demolished Virginia Ordnance Works (VOW) near Glen Wilton, Virginia (Figure 1). The purpose of this report was to partially fulfill the goals of a larger project that entails not only this specific historic investigation, but also a national context for the World War II Ordnance Department's Government-Owned Contractor-Operated (GOCO) industrial facilities, 1939-1945 (Kane 1995); detailed investigations into the history of seven former World War II-era Ordnance Department GOCO industrial facilities (present-day Badger, Indiana, Joliet, Kansas, Radford, Ravenna, and Twin Cities army ammunition plants); and photographic documentation of the same sample installations. Goals of the larger project included investigation and documentation of World War II and pre-World War II buildings and structures now under the jurisdiction of Army Materiel Command (AMC) as part of a Legacy Resource demonstration program of assistance to small installations, as well as the completion of mitigation efforts stipulated in a 1993 Programmatic Agreement among the AMC, the Advisory Council on Historic Preservation, and multiple State Historic Preservation Officers concerning a program to cease maintenance, excess, and dispose of particular properties. The detailed historic investigation of Radford Army Ammunition Plant, like the detailed historic investigations for the other sample installations, was undertaken in order to develop the national historic context on a state and local level. The major focus is upon the impacts of the facility on state and local history.

In September 1993, Geo-Marine, Inc. (GMI), was contracted by the Army Corps of Engineers, Fort Worth District, to complete the national historic context, detailed historic investigations, and photographic documentation. Duane Peter, Director of the Cultural Resources Division at GMI, served as Principal Investigator. The research for the Radford Army Ammunition Plant detailed historic investigation was subcontracted to Gray and Pape, Inc., and in early 1995, Ashley M. Neville and Debra A. McClane conducted the research. The work was performed under Delivery Order No. 014 of Contract No. DACA63-93-D-0014.

Chapter 2 of this report describes the objectives of and the methods used in the detailed historic investigations. Chapter 3, the historic context portion of the report, is divided into ten major sections. The first presents general information about the ROW, the second, about the NROP. The third consists of a brief description of the ROW from the end of World War II to the present. The fourth part of the chapter presents details on the military/political history of the facility. Architecture/engineering design is the subject of the fifth section within the historic context. The sixth, seventh, and eighth sections discuss the design,

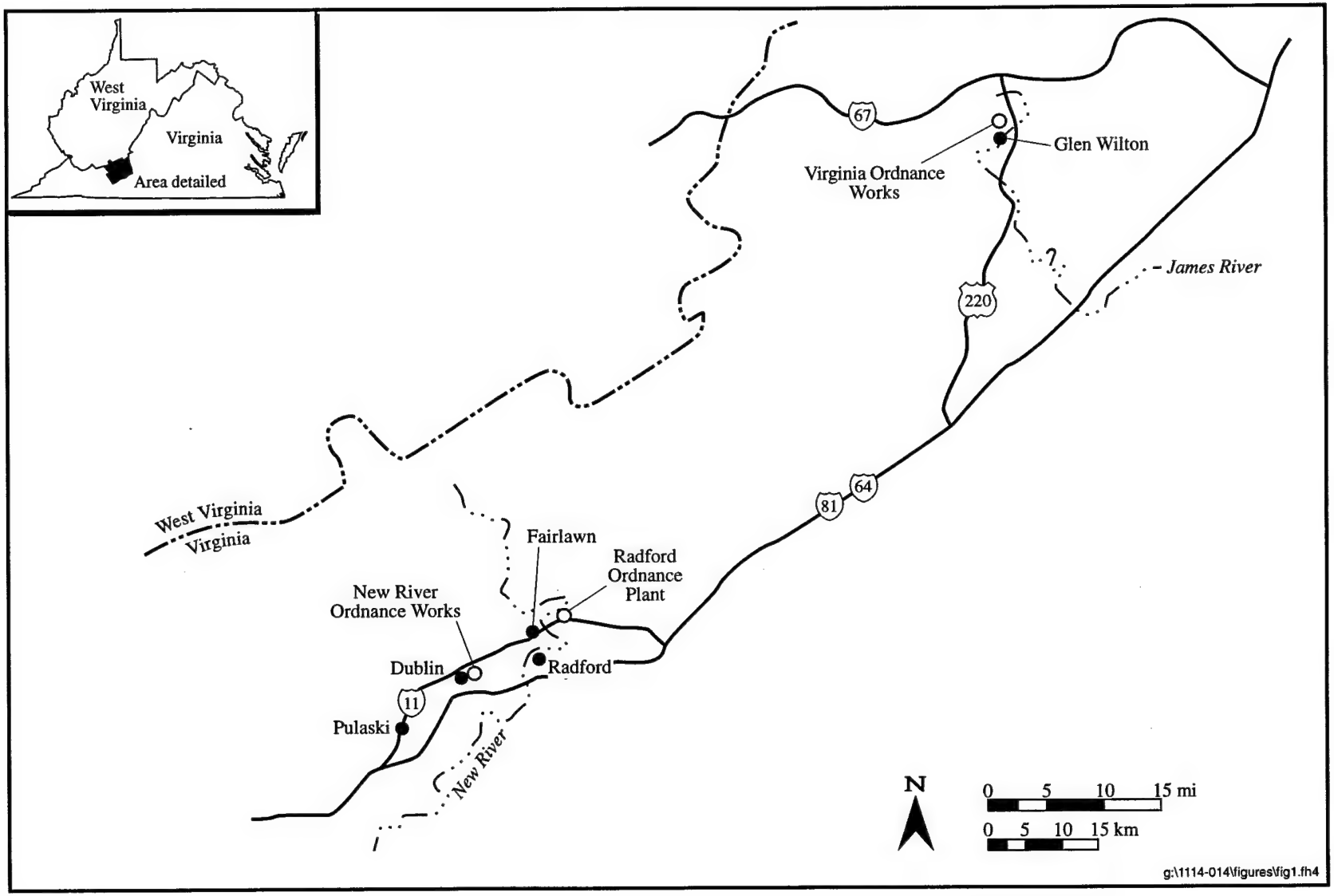

Figure 1. Locations of the Radford Ordnance Works, New River Ordnance Plant, and Virginia Ordnance Works in Virginia.

construction, and operation of the ROW, NROP, and VOW, respectively. Social history is discussed in the ninth section. The tenth and final section of Chapter 3 consists of a summary and conclusions. A list of references cited follows the body of the report.

CHAPTER 2
OBJECTIVES AND METHODS

OBJECTIVES

The research effort at RAAP was undertaken to partially fulfill objectives of a larger project, the goals of which were to "research and document World War II and earlier buildings and structures at number of ammunition plants under the jurisdiction of the Army Materiel Command (AMC) as a Legacy Resource Program demonstration project for assistance to small installations" and to "fulfill mitigation efforts of a 1993 Programmatic Agreement among the AMC, the Advisory Council on Historic Preservation, and Multiple State Historic Preservation Officers concerning a program to cease maintenance, excess, and dispose of certain properties" (SOW 1993:1). The SOW further set forth the primary goal of investigations into individual facilities, including RAAP, that goal being to "provide [an] understanding of the World War II military-industrial complex through detailed examination of the sample installations [RAAP is one of seven], expanding the national historical context." The SOW also stated that the investigation was to focus "on World War II social issues of state and local significance, . . . [including] 1.) Controversies over Government acquisition of the land, 2.) How the change in the labor base affected of the *[sic]* local areas, 3.) Impacts women and blacks had in the local work force, etc." (SOW 1993:4).

METHODS

The research methodology involved the examination of numerous graphic and written resources that provided both a national overview of the political, social, technological, and architectural context and more specific information regarding the history of the Radford Army Ammunition Plant and its effect on the surrounding community. Information on the national context was attained from a variety of books and reports including the first volume in this series *Historic Context for the World War II Ordnance Department's Government-Owned Contractor-Operated (GOCO) Industrial Facilities, 1939-1945* (Kane 1995)[1].

Unpublished sources of information were identified and made available by Geo-Marine, Inc., the prime contractor for this project, through research at the Suitland Reference Branch of the National Archives and at the Command Historical Office of the U.S. Army Armament, Munitions and Chemical Command (AMCCOM) at Rock Island Arsenal. These sources include a three-volume history of the Radford Ordnance

[1] The section on the military and political environment draws heavily from Kane (1995), which should be referenced for a more comprehensive discussion of the national setting.

Works (ROW) by Hercules Powder Company, the operating contractor, that provided much of the information contained in this report. A one-volume plant history written by the Commanding Officer and Constructing Quartermaster in 1941 and a one-volume basic history prior to 1942 also provided useful data.

The Radford Army Ammunition Plant was the primary focus of research. The archives were visited and pertinent data collected including a one-volume history of the New River Ordnance Plant and numerous historical and informational brochures. The plant newspaper, found in the RAAP Library, provided valuable information. The File Room was the source of drawings and plans for the installation. The Media Service Department at RAAP was also consulted; however, few early photographs of construction or of the facility were located. Joann Jenkins, Operations Review, RAAP, provided access to the plant and its archives. Terry Thompson, Land Management Specialist with Hercules, provided tours of the installations and sought out requested materials and information.

Area repositories were also visited for published and unpublished resources on RAAP as well as information on the impact of the plant to the surrounding area. The microfilm files of the Newman Library at Virginia Polytechnic Institute and State University (VPI&SU), Blacksburg, Virginia, were consulted for early editions of Montgomery County newspapers as well as histories of the region and information on defense housing in the area. The McConnell Library at Radford University and the Radford Public Library, both located at Radford, Virginia, were visited and provided information on Radford area history. Unfortunately, no archival copies of the Radford newspaper exist and, thus, little information from that source was available. The Roanoke Public Library, Roanoke, Virginia, provided local history and information from the Roanoke newspaper, the *Roanoke Times & World News*. The Roanoke Regional Preservation Center of the Virginia Department of Historic Resources provided local histories and information on defense housing in Radford. Other repositories consulted include the Library of Virginia, and the Archives of the Virginia Department of Historic Resources, both of Richmond, Virginia.

Much of the information on the Virginia Ordnance Works came from a few specific sources. Mike Hudson of the *Roanoke Times & World News* and George Tolley, an archaeologist with the George Washington National Forest, were contacted and contributed much of the information on the plant. Further research in the Botetourt County records was undertaken by Doris Alderson.

In addition to these textual resources, five oral history interviews were conducted and taped. All of the informants had been residents of the Montgomery/Pulaski County area before construction of the installation began. Three of the subjects have retired from RAAP: two men, Mr. Walter B. Harman and Mr. Leo S. Stanger, eventually held supervisory positions in Roads and Grounds, and Security (respectively), and the one woman interviewed, Alene Graham, worked in the Payroll Department for Hercules from 1943 to 1991. One present employee in production, Mr. Howard Johnson, was also interviewed. He has the longest tenure of all current employees. The fifth informant was a long-time resident of Radford, Mr. Robert Bruce. Mr. Bruce, who is 96 years old, worked for the Norfolk & Western Railroad (now Norfolk Southern) in Radford. His daughter, Shirley Bruce, who was a child when the RAAP was constructed, was also present during the interview.

Mr. Harman, Mr. Stanger, and Mr. Johnson had worked at ROW briefly (about six months or so) during the World War II period before being drafted into the service. Upon their return, the plant had been largely shut down and it was not until the Korean War build-up began in the early 1950s that they held permanent jobs at ROW. It was not possible to locate and arrange taped interviews with people who worked at the plant during its construction or at the beginning of production in the early days of World War II. Of the workers who consented to participate in a taped interview, Alene Graham, the only one who had worked at RAAP during World War II, was not employed until 1943.

Two former employees of RAAP and a member of one of the area families were contacted by telephone and proved to be invaluable sources of information. The two former employees both came to the area from

elsewhere expressly to work at the installation. Charles Flynn began as an inspector for the Army but spent 31 years as Executive Assistant to the Commanding Officer. John Horvath was a chemist and engineer who worked at Radford from 1940 to 1942, was then transferred to Sunflower Ordnance Works in Kansas, and returned to Radford in 1960. Mr. Horvath is uniquely qualified to give a broad overview of ordnance plants in the United States as well as specific information about RAAP. Both also provided information on defense housing in the area. Janie Hardwicke also was contacted by telephone. Her family owned land that was seized by the government for the construction of the New River Ordnance Plant. A young schoolteacher at the time, she provided information from the perspective of a former property owner who had to deal with being displaced by the installation as well as the effects the boom town had on her community.

Mason & Hanger Engineering, Inc., the construction and engineering company that built both the Radford Ordnance Works and New River Ordnance Plant, was contacted. Dr. James E. Mickey Jones, Vice-President, furnished a history of the firm that not only provided information about these projects but of other GOCO installations as well. This timely information added another dimension to this history.

Although every effort was made to double-base-check oral histories, in some cases the taped interviews provided insights not available in the written histories. Nonetheless, the frailty of human memory over a 50-year time span should be taken into consideration when producing a report of this nature. The reliability of second-hand information should also be kept in mind. Joann Jenkins and Terry Thompson, both currently at RAAP. contacted a number of present employees to secure information on the plant, particularly on the survival of original equipment. However, the longest-serving employees at RAAP today began work there in the 1950s and probably have no first-hand knowledge of the original equipment. When asked for information about surviving original equipment or processes, they responded to the best of their knowledge but their information may have been acquired from other employees who are now retired or deceased.

It should also be noted that a number of inconsistencies were found between the various plant histories as well as within individual volumes. Different dates for one event or different amounts of product produced are examples of this type of problem. Every effort was made to reconcile these differences and it is felt these inconsistencies do not affect the overall report.

CHAPTER 3
HISTORIC CONTEXT FOR RADFORD ORDNANCE WORKS, A WORLD WAR II ORDNANCE DEPARTMENT GOCO INDUSTRIAL FACILITY, 1940 - 1995

The Radford Army Ammunition Plant (RAAP) is a government-owned contractor-operated (GOCO) installation that was constructed under the government's National Defense Program to supply the United States and her allies with badly needed ordnance materials for World War II. Today RAAP includes the main manufacturing plant, known as the Radford Unit, and a magazine storage facility, the New River Unit (Figure 2). The New River Unit was formerly the New River Ordnance Plant and is all that remains in government ownership from the World War II load, assemble, and pack (LAP) plant. For a period of nine months in 1942 the Virginia Ordnance Works, a TNT facility, was operated by Hercules Powder Company as a part of the Radford Ordnance Works. It was located about 50 miles away in Glen Wilton, Virginia (see Figure 1).

During the war, Radford manufactured 44 types of propellant with an amazing production pace that eventually reached 170 percent of its initial rated capacity. It was the first of the ordnance plants to go into production and was the first plant to manufacture pentolite. It was awarded five consecutive Army-Navy "E" awards for excellence in production and four service stars. Radford trained more than 1,100 employees to operate other Ordnance Plants (Anonymous [1966]) and had its own research and development department. It was also the first plant to employ women in large numbers in smokeless powder production (*Radford Plant Weekly*, [*RPW*] 1945h:1).

RAAP encompasses 6,901 acres in two units and is situated in the foothills of the eastern slope of the Appalachian Mountains of southwestern Virginia in Montgomery and Pulaski counties. The main manufacturing plant contains 4,080 acres (Harman 1989) and is located approximately seven miles northeast of the city of Radford and eight miles southwest of Blacksburg. Radford has a population of 16,587, including the 8,500 students of Radford University, while Blacksburg has a population of about 34,590 which includes the 22,000 students of VPI&SU. Roanoke, the largest city in the region with 94,877 residents (Anonymous 1995), is about 50 miles northeast of the plant. The Radford plant is situated on rolling land between sharp ridges. The historic New River, perhaps the oldest river on the North American continent (Frye 1991:205), flows through the plant creating the famous Horseshoe Bend.

During World War II, what is now the Radford Army Ammunition Plant was two separate facilities: the Radford Ordnance Works (ROW) and the New River Ordnance Plant (NROP). There are differences between a works and a plant.

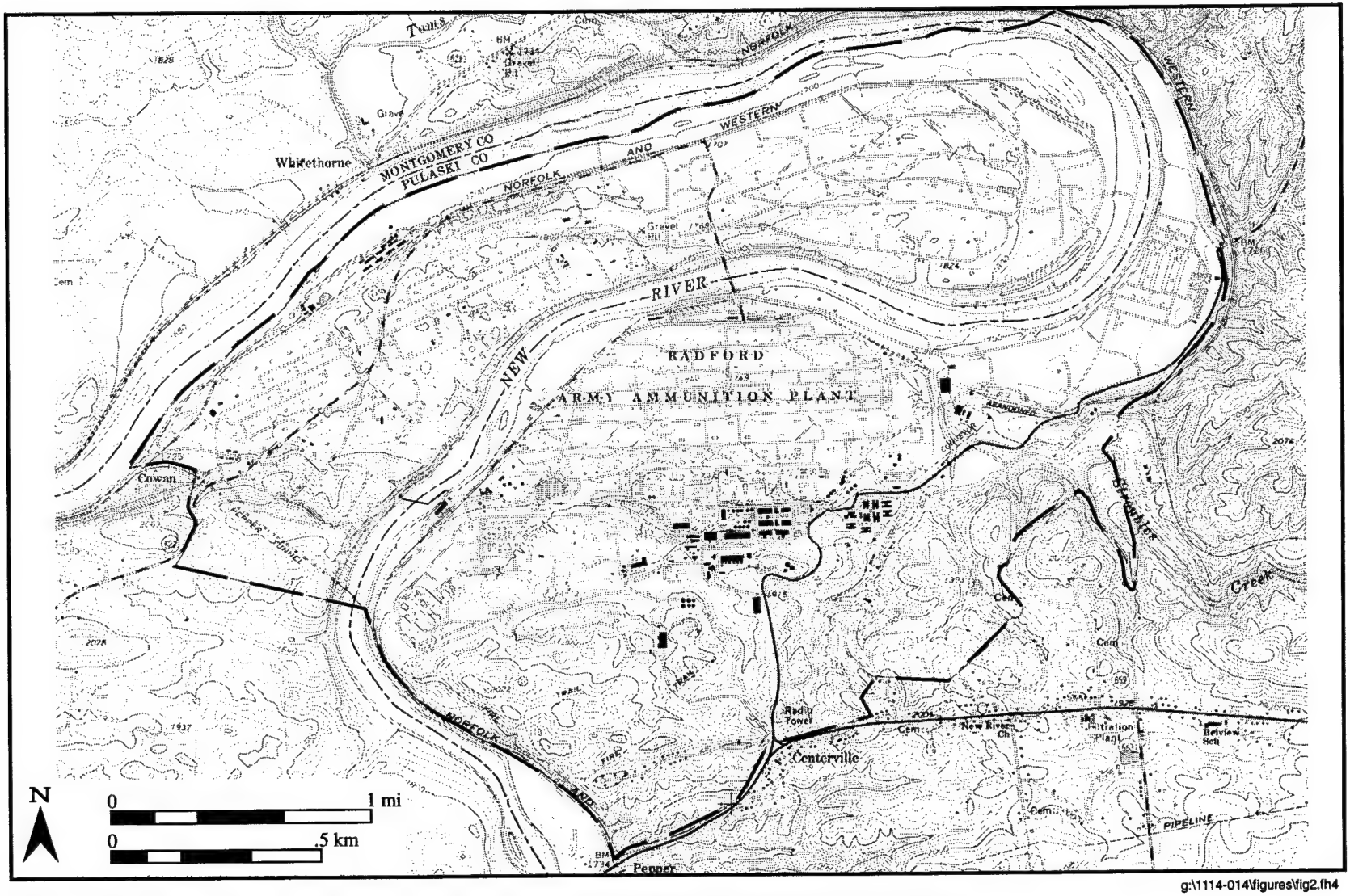

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Figure 2. USGS Radford, Virginia, map showing a more recent depiction of the layout of the Radford Ordnance Works.

> An installation is a plant if only 'fabrication or assembly' took place there; it is a works 'if basic materials were required for production' (Thomson & Mayo 1991:32). Load, assembly, and pack facilities . . . were identified as plants during World War II. Facilities that manufactured powder, explosives, chemicals, or incendiaries were classified as works (Kane 1995:7-8).

Hence, Radford was a works and New River a plant.

In September 1943, the NROP was transferred to the jurisdiction of the ROW. Late in 1945 ROW was designated the Radford Arsenal with the NROP as a sub-post. In January 1950 the sub-post designation was eliminated and the NROP became an integral part of the Arsenal. In 1961 the installation was renamed the Radford Ordnance Plant and remained so until it was designated the Radford Army Ammunition Plant (RAAP) in August 1963 (MacDonald and Mack 1984:14).

RADFORD ORDNANCE WORKS

On August 16, 1940, the Chief of Ordnance signed a cost-plus-fixed-fee (CPFF) contract with Hercules Powder Company for the design, construction, and operation of a plant, the Radford Ordnance Works, to manufacture smokeless powder. Hercules had begun as an explosives company for the mining industry, gun owners, and the military, and on the eve of World War II, it was the largest producer of naval stores and the third largest producer of explosives in the nation (Derdak 1988:343, 344). During the war, Hercules became the contractor-operator of at least six GOCO facilities, including ROW. Subsequent to World War II, Hercules continued as the Radford contractor-operator until April 1, 1995, when Alliant Technical Systems became the operator (Terry Thompson, RAAP, personal communication 1995).

The ROW was the second smokeless powder plant to be authorized as part of the National Defense Program, with the contract being signed slightly less than a month after the contract for the Indiana Ordnance Works (IOW) was signed. Although the IOW Plant 1 and ROW are thought of as the first two World War II-era smokeless powder plants, they were only the first of the Ordnance Department government-authorized facilities. The Anglo-French Purchasing Board had contracted privately with Du Pont on June 10, 1940, to build and operate an explosives plant at Millington, Tennessee. This privately owned plant, the Tennessee Powder Company, was later transferred to the War Department on February 22, 1942, and renamed the Chickasaw Ordnance Works (Kane 1995:31).

Hercules Powder Company performed the design and engineering for the plant's construction with Mason & Hanger Company of New York as the primary construction contractor (Anonymous n.d.c:1). Construction of the plant began on September 7, 1940, and at the height of construction in March 1941 there were 23,150 employees (*RPW* 1941b:4). Radford Ordnance Works was dedicated on March 14, 1941, and production of powder began on April 5, 1941, three months ahead of schedule. (*RPW* 1941c:1).

The original layout design for ROW was based in large part on Hercules' smokeless powder plants in Kenvil and Parlin, New Jersey. However, a major explosion at the Kenvil plant on September 12, 1940, caused a rethinking of the design for ROW. The original specifications called for a two-line powder plant with provision for a six-line plant if needed. Because of the Kenvil disaster, increased distances between buildings dictated that the Radford site could only accommodate three lines. Several weeks delay was caused when designs and layouts had to be redrawn (Hercules Powder Company [HPC] [1945]a:66).

ROW was more diversified in its operations than any of the other smokeless plants during World War II. It was not the quantity of product it produced, but the variety of its products that was important (John Horvath, personal communication 1995). That description of ROW, which applies from World War II to the late twentieth century, is justified both from the "viewpoint of the many types of propellants produced, and

from the physical propellant grains themselves [that] range in size from smaller than BB shots up through large grains for tactical rocket motors" (Anonymous 1970:2).

Radford Ordnance Works was part of the "first wave" of manufacturing arsenals built under the GOCO initiative. ROW was one of the first of the defense plants to go into production, which began on April 5, 1941 (Murphey 1993b:Appendix). ROW and Indiana Ordnance Works were built as smokeless powder plants since there were only a handful of active smokeless plants in the country at that time. The government estimated that the existing manufacturing plants could produce only five percent of the needed munitions for the possible eight to ten million Allied forces (Murphey 1993b:3). Only two of the six government plants, Picatinny and Frankford, were capable of producing smokeless powder. Because of the explosion at Hercules' Kenvil plant, the government increased ROW production quota of powder to 300,000 pounds per day, with 50,000 pounds of small arms powder and 250,000 pounds per day of cannon powder (Baldwin 1942:25). This pressing need for smokeless powder was the main objective behind the ROW project.

NEW RIVER ORDNANCE PLANT

The New River Plant, originally a load, assemble, and pack facility (LAP), is located about 12 miles southwest of the main plant near Dublin, Virginia, population 2,012, and currently contains 2,821 acres (Harman 1989). Although it was called the New River Ordnance Plant, it was not located on the New River. It was planned originally to occupy the Horseshoe Bend section of the Radford works but after the ROW layout change there was insufficient space at that location. A new site in Pulaski County some 12 miles southwest of the manufacturing plant was chosen.

NROP was designed and operated by Hercules Powder Company as a separate plant although it was under the same commanding officer as ROW. Construction was begun by Mason & Hanger in February 1941; the plant was completed and in operation by January 1942. By May 1943 it had been decided to terminate bag loading operations at NROP and place it in stand-by. The storage magazines were to be operated as a Storage Depot (HPC [1945]a:1374). Between September 1943 and July 1944 operations at New River were confined to the waterproofing of trench-mortar increments and the handling of powder into and out of storage. From July 1944 to the end of the war, the plant again operated as a full-scale propellant loading facility (HPC [1945]b:317).

At the end of World War II, the NROP was closed and classified as surplus; however, in April 1946 the magazine area (propellant storage) was withdrawn from surplus and placed in a stand-by status. Between December 1946 and January 1948 large parcels of the manufacturing area were sold (MacDonald and Mack 1984:31) and today are part of an industrial park. Currently, the only two buildings standing at NROP, in addition to the storage magazines, are a guard house and small search house. All other buildings and equipment either have been sold or dismantled.

POST-WORLD WAR II

With the cessation of hostilities in August 1945, the ROW was put into stand-by condition and turned over to the government in late 1945. Beginning in June 1946 the Radford Arsenal produced ammonium nitrate as part of the War Department's fertilizer production program. In 1949 it was again awarded a contract to produce rocket propellant and RAAP as been in continuous production since. During the post-World War II period, Radford produced cast propellant for rockets such as the Honest John, Little John, Nike Atlas, and Nike Hercules rockets (Anonymous 1970:3). Today the plant produces double-base, triple-base, and high energy propellant powder.

MILITARY/POLITICAL

Planning the GOCO Ordnance Plant/Ordnance Works System

The national historic context, *Historic Context for the World War II Ordnance Department's Government-Owned Contractor-Operated Industrial Facilities, 1939-1945* (Kane 1995), provides a more detailed explanation of the events and policies that shaped the planning effort and the resultant GOCO Ordnance Plant/Ordnance Works system. A brief summary discussion of the major events is presented for this study. The confused and wasteful experience of the mobilization effort during World War I taught the military that planning, particularly for priorities and balanced production, was key to a successful procurement program. Although the country was intensely isolationist after World War I, planning efforts were begun in a small way soon after the war. These efforts grew with the increasing military tensions in the 1930s and the increased military budgets that corresponded to the tensions.

The Interwar Years: Procurement Planning (1918-1941)

The planning effort for procurement began just after World War I. The ill-planned experience during that war convinced military planners that planning was essential for well-organized and rapid preparations for war in the future. One of the first measures was Congressional approval of the National Defense Act of 1920, which among other purposes, delineated responsibility for procurement planning through the Assistant Secretary of War. In 1922, 13 Ordnance Districts were established throughout the country and played a key role in procurement planning and the GOCO industrial facilities program during the war. The government's six arsenals were also extremely important in the planning efforts because of their individual specializations in the manufacture of a particular kind of materiel and the fact that these arsenals were the storehouses for detailed information on these manufacturing processes.

During the years between the wars, the Ordnance Districts kept in contact with private industry regarding the availability of existing facilities for war-time conversion, machine tool surveys, and the placement of Accepted Schedules of Production with private manufacturers. The Accepted Schedules of Production were agreements that listed the amounts of materiel that would be produced if war occurred. The arsenals developed plans and layouts for implementation of the manufacturing processes by private industry, which were later used as the preferred models for the GOCO industrial plants. The Picatinny Arsenal in Dover, New Jersey, was the center for layouts and specifications for GOCO LAP facilities (Walsh 1984:18).

U.S. Gears Up For War

Armament planning was regarded as a necessity not only because of the past experience during World War I, but because there were strong signs that war could become a reality in the near future. During the 1930s, increasing military tensions abroad caused the military appropriation budget to rise; between 1934 and 1935 the budget rose from $7,048,455 to $11,049,829. In 1938, Germany's further aggressions caused an increased level of funding by Congress that augmented planning funds and made possible the purchase of equipment for LAP, small arms ammunition, and powder facilities. In this same year, educational orders were authorized to be placed with private industries for certain materiel in short supply or that were difficult to manufacture. These educational orders were changed to defense contracts in 1940 after Germany invaded France. Production studies, which involved contracts to private companies for the determination of equipment and methods for mass production of ordnance items, were another means of planning.

The placement of overseas orders aided the U.S. in its build-up for war despite neutrality laws. In 1938, European countries began to order supplies from the U.S. through a loophole in the legislation that allowed

these governments to obtain the supplies through the payment of cash and delivery on their own ships; battle supplies, however, were exempted from this policy. With the invasion of Poland and other Eastern European countries in 1939, Britain and France declared war on Germany. The neutrality legislation was changed then to allow foreign countries to buy surplus U.S. materiel.

Just before France fell to the Germans on May 27, 1940, President Roosevelt declared a state of limited national emergency. From this time until December 1941, Congress voted to fund the Ordnance Department's budget many times over the 1920 appropriation. This period became the crucial 18 months that military planners theorized was the minimum time needed to prepare for war. The first national defense appropriation act was passed in June 1940. In that same month Congress passed supplemental acts that included funds for the construction of GOCO facilities. The first contract for a GOCO facility was signed in July 1940 with E. I. du Pont de Nemours & Company for a smokeless powder plant in southern Indiana. The LAP facility at Ravenna, a propellant and explosives plant in Radford, Virginia, and a tank arsenal in Detroit were the next three contracts, all signed in August 1940.

Planning for the Installation

The locations of the GOCO plants were determined by several primary factors that were mainly related to the geographical and industrial characteristics of the vicinity. These factors included the necessity of existing railroad lines near the plant location for shipping purposes, level but relatively inexpensive land, an inland location more than 200 miles within the country's borders to minimize the possibility of enemy attack, a large available pool of labor and materials (e.g., cotton and water for powder plants), remoteness from large centers of population due to the potentially hazardous character of the operations, and the proximity of other war materiel production plants. An additional, though unstated, factor that motivated the choice for a particular location involved political influence.

As early as July and August 1938, representatives from the Du Pont Company visited Radford at the suggestion of T. Gilbert Wood, Industrial and Agricultural Agent for Norfolk and Western Railway Company (Baldwin 1942:6). It was not uncommon for railroads to play a major role in the site selection process, lobbying for location within their area of operation. It was not until March 1940, however, that railway officials were notified that the Radford property had been recommended as the site for the establishment of a munitions plant. On July 30, 1940, Wood made arrangements for inspection of the site by representatives from the National Defense Council, the Ordnance Department, and the War Department. Following the inspection, the committee reviewed the appropriateness of the site vis-a-vis the "desirability of the properties at Cowan and Pepper, adequate water supply, proximity to coal mines and chemical plant, double track line of the Norfolk and Western Railway, railroad yard facilities at Radford, Pulaski, Bluefield and Roanoke, protection afforded by mountains, favorable climatic conditions, [and] efficient Anglo-Saxon labor . . ." (Baldwin 1942:8). "Proximity to main railroad lines and to adequate amounts of suitable labor was considered to be more important by the Ordnance Department's Site Committee and the early GOCO contractors who were advising them" (Gaither 1994:17).

Nestled within the Appalachian and Blue Ridge mountain ranges, Radford was geographically well-protected. The town of Radford lay safely away on the other side of the New River and the proposed area was completely rural in character. The placement along the New River ensured an adequate supply of water and the proximity of the bituminous Pocohontas coal fields of Virginia and West Virginia ensured a fuel source. Laborers could be obtained from nearby counties and even into West Virginia and North Carolina. Finally, service by the Norfolk and Western and the Virginian railways ensured that labor and products could arrive and leave on schedule. Railroad interests were instrumental in site selection for Radford, as well as for the Weldon Springs plant in Missouri (Kane 1995:24).

The site of the propellant and explosive (P&E) plant affected the site selection of the load, assemble, and pack facility. On December 17, 1940, Hercules signed a contract to design and operate the New River Ordnance Plant, located just 12 miles away from Radford Ordnance Works. The New River plant operated as a bag loading facility for the smokeless powder produced at Radford. This "pairing" of facilities occurred in other instances, as well: Indiana Ordnance Works and Hoosier Ordnance Plant; Kankakee Ordnance Works and Elwood Ordnance Plant; and Longhorn Ordnance Works and Lone Star Ordnance Plant.

ARCHITECTURE/ENGINEERING DESIGN

Architect-Engineer Firm

Ordnance officials favored the use of contractor-operated firms as project engineers; that is, the company that was to run the plant would also build it. Ordnance also argued that one firm should act "not just as architect-engineer and contractor-operator, but as architect-engineer, construction contractor, and contractor-operator" (Kane 1995:33). The Quartermaster Corps (QMC), however, urged a division of responsibilities as a way to maintain government control and authority. By June 1940 this conflict between the two branches reached a confrontation. A compromise recommended that the Ordnance Department participate in the selection of the architect-engineer and construction contractors but QMC would retain the primary responsibility for these tasks. General Charles M. Wesson, Chief of Ordnance, attempted to circumvent this decision with swift action and signed a contract with Du Pont for the Indiana Ordnance Works on June 17, 1940. In the end he was forced to back down and accept the compromise plan (Kane 1995:33).

When the contract for Radford Ordnance Works was signed, it called for Hercules Powder Company to be the prime contractor performing both design and construction as well as the operation of the plant (HPC [1945]a:52). Although Hercules anticipated preparing all estimates and designs, the situation became such a rush job that Mason & Hanger, the construction subcontractor, actually completed much of this work. Having performed ordnance work in World War I with favorable review and having designed Hercules' private smokeless powder plants, Mason & Hanger was a trusted ally in the ROW endeavor.

Hercules Powder Company

The Hercules Powder Company was one of 64 small explosive companies that E.I. Du Pont de Nemours acquired during the last part of the nineteenth and early twentieth centuries. By 1906 Du Pont controlled 70 percent of the U.S. explosives market. Documents presented to the U.S. Department of Justice by a one-time Du Pont business partner led to a suit against the company for violation of the Sherman Anti-Trust Act. Filed on July 7, 1907, the suit charged that Du Pont's dominance of the explosives industry was, in effect, "a restraint of interstate trade" (Dutton 1942:193-194). After four years of litigation, the federal court ordered Du Pont broken up. With approval from the federal government and the court, Du Pont divided into three companies on December 15, 1912—Du Pont, the Hercules Powder Company, and the Atlas Powder Company. Although set up as independent corporations, Hercules and Atlas both maintained close personnel ties to their parent corporation, and until the 1970s, the president of Hercules was a Du Pont relative (Derdak 1988:343).

Hercules was the larger of the two new corporations. In the Du Pont settlement, Hercules received eight black powder mills, three dynamite plants, and the Laflin & Rand patents for the manufacture of smokeless sporting powder. "Its authorized capital was $6,500,000 in common stock and a like amount in six per cent *[sic]* income bonds. . . ." (Dutton 1942:198). The new companies were also allowed by the court to utilize Du Pont's engineering, chemical, and purchasing departments for five years (Dutton 1942:199). With these assets, Hercules quickly became one of the larger chemical companies in the U.S.

Throughout its history, Hercules has been proud of its "long-standing ability to turn waste materials into useful, valuable products for a wide spectrum of needs" (Brown & Giacco 1977:16). In 1916, through a contract with Britain, Hercules harvested giant kelp from which to produce acetone. In 1920 Hercules began to produce "cotton cellulose" from leftover fibers on processed cotton seeds. This product, when soaked with nitroglycerine, becomes nitrocellulose, which would be one of ROW's major products (Derdak 1988:343).

During World War I, Hercules contracted with the U.S. government to supply smokeless powder and TNT. These contracts and increased demands required Hercules to increase investment in their existing plants. The government also called on the company to operate the newly constructed "Nitro" plant in Charleston, West Virginia. During these years, Hercules' production capacity grew considerably. The total volume of ordnance produced by Hercules from 1916 to 1918 was "46 million pounds of cordite, 71.5 million pounds of TNT, 55.6 million pounds of smokeless powder, and massive amounts of acetone, ammonium nitrate, and other products with a total value of $116.5 million" (Dyer and Sicilia 1990:110).

It was during this period that Hercules diversified into chemicals, rather than remaining strictly an explosives company. Along with its increase in production capabilities, Hercules also developed its own purchasing, engineering, and research departments, ending its reliance on Du Pont's departments. These years were a time of transformation and maturation for the company. The experiences encountered during World War I were instrumental in how the company would function in the future:

> Between 1914 and 1918, operation of smokeless powder and solvent plants had required Hercules to develop new abilities in research and analysis, to master new skills in construction and engineering, and to learn new techniques of managing on a scale much greater than ever imagined before the war (Dyer and Sicilia 1990:111).

One of the company's failures came in its naval stores endeavors. In 1920, anticipating a shortage of naval stores (products derived from pine sap such as gums, turpentines, and various adhesives), Hercules quickly began overproduction of these products. The shortage never occurred and Hercules was stuck with its production facilities and stock (Derdak 1988:343). In typical fashion, however, Hercules diversified its production to consume these stocks. The naval stores division represented the company's second largest permanent investment, but produced the smallest percentage of the company sales (Derdak 1988:343-344). Instead, it was the explosives division that got the company through the Depression.

To assist in the selection of the contractors for the GOCO facilities, in July 1941 Brigadier General Charles D. Hartman created a Construction Advisory Committee. This committee was requested to gather information on cost-plus-fixed-fee construction and architect-engineer contractors, to recommend contracts, and to act as a liaison with the construction industry (Kane 1995:34). Hartman gathered information on firms "in good financial condition, with a good record for the past five years, with high quality management staffs and with recent experience in work similar in cost and amount to work they would undertake for the army" (Kane 1995:33). For GOCO facilities, "industrial experience and skill in heavy construction" were also considerations (Fine and Remington 1972:185).

Although chosen for a variety of reasons, whenever possible the GOCO contracts were let to those companies with experience in manufacturing the desired product (e.g., smokeless powder) or a similar product. In 1940, the few companies that had extensive experience with propellants and explosives included Atlas, Du Pont, Hercules, and Trojan (Kane 1995:32).

As a government contractor, Hercules possessed all the characteristics desired by the Ordnance Department. The company's diversification resulted in five divisions: explosives, naval stores, nitrocellulose, chemical cotton, and paper products (Derdak 1988:344). The company was active in research and development in each of these fields. In production capacity, Hercules was the second largest producer of explosives in the

U.S. at the beginning of the war. In WWI, Hercules had learned to deal with expanded employment and product demand. The company had also demonstrated its ability to develop and manage new technologies. "The rapid buildup of the 1940s certainly swelled sales and employment and again changed the mix of business. This time, however, change did not betoken transformation: Hercules simply did what it already knew how to do, albeit on a much expanded scale" (Dyer and Sicilia 1990:221). Experience counted for much during the first wave of GOCO construction.

ROW was the first of six GOCO plants that Hercules engineered and operated (Dyer and Sicilia 1990:228-229). On August 16, 1940, the U.S. Government contracted with the Hercules Powder Company on a cost-plus-fixed-fee basis to "acquire the site, design (including plans, drawings and specifications), construct, equip (including the plans for the installation of the equipment) and operate a certain nitrocellulose smokeless powder plant at or near Radford, Virginia" (Baldwin 1942:33). The company also operated Badger Ordnance Works (1943, Baraboo, Wisconsin), Missouri Ordnance Works (1942, Louisiana, Missouri), New River Ordnance Plant (1941, Pulaski, Virginia), Sunflower Ordnance Works (1943, DeSoto, Kansas), Virginia Ordnance Works (1942, Glen Wilton, Virginia), and Volunteer Ordnance Works (1942, Chattanooga, Tennessee) (HPC [1945]a:1365; Murphey 1993b:Appendix). The output for Hercules production during World War II is presented in Table 1.

Hercules also organized their internal departments to better meet the requirements for such a large project within the compressed time schedule. In their drafting division, squads were formed to cover specific areas: structural, power, acid, electrical, nitrocotton, and smokeless powder. All engineering work was under the direct supervision of Luke H. Sperry, chief engineer, and E. S. Wilson, assistant chief engineer. The design and drafting departments were similarly organized and were headed by H. F. Wendle, project engineer, and F. A. Hodge, assistant project engineer (HPC [1945]a:53).

In anticipation of a government contract, preliminary design began on July 1, 1940. It followed the general design of Hercules' Parlin plant for nitrocotton and the Kenvil plant for smokeless powder. This design consisted of advanced development of capacities, equipment, quantities of utilities, and location plans for a compact workable plant (HPC [1945]a:55).

Mason & Hanger

The engineering firm of Mason & Hanger-Silas Mason Company, Inc., currently the oldest continually operated engineering construction firm in the United States (James E. Mickey Jones, personal communication 1995), has its roots in the Mason Syndicate, founded in 1827 by Claiborne Rice Mason (1800-1885) of Chesterfield County, Virginia. About 1870, the Mason Syndicate became Mason & Hoge (Lemert 1979:22). Charles Eugene Hoge served as a supervisor, but was chiefly the overseer of the firm's financial affairs. He later withdrew from the company to pursue his banking interests. In 1891, Harry Baylor Hanger was named a partner in the firm. Hanger had worked his way up in the company, starting as an assistant to C. R. Mason in 1881. He served as a bookkeeper, then camp manager, and in 1888 became a stockholder (Lemert 1979:29). Hanger stayed with the firm until his death in 1925. Upon Hanger's death, Silas Mason, grandson of C. R. Mason, became president of the firm. In 1926 he incorporated part of the firm as the Silas Mason Company to conduct the contract for a rock tunnel in New York City (Lemert 1979:49).

The firm won a reputation as bridge and road builders and tunnel diggers for the C & O Railway and later the Confederate Army. From the 1890s through the 1920s, Mason & Hanger won prominent contracts for tunnel and canal work in such cities as Boston, New York, and Chicago. The firm also constructed subway cuts, navigation locks, and dams during this period. A New York office was established through the firm's numerous contracts in the north.

Table 1
Production of Military Explosives During World War II by Hercules Powder Company
(Pounds of Powder Packed or Prepared for Delivery: January 1, 1941, to December 31, 1945)

Plant	Badger	Radford	Sunflower	Volunteer	Kenvil	Belvidere	Grand Total
Small Arms, single-base	102,219,528	73,307,772	11,682,847		40,546,165	20,515,712	248,272,024
Cannon, single-base	146,933,885	430,124,960	71,503,113		16,653,730	94,509,491	759,725,179
Cannon, double-base		32,990,789	1,950,097		21,071,454		56,012,340
Trench mortar increments		11,494,504			943,230		12,437,734
Rocket propellant, solventless	13,946,512	2,857,188	82,388,419				99,192,119
Rocket propellant, solvent		10,794,498	15,329,317		528,454		26,652,269
E. C. Blank Fire	1,644,500				2,384,564		4,029,046
Experimental powders		623,807					623,807
Reclaimed and reblended powders	7,171,027	1,781,763	16,703,735			25,656,525	
Pentolite		27,661,415				27,661,415	
TNT		4,846,150		828,640,744		833,486,894	
Total	271,915,452	596,482,846	199,557,528	828,640,744	82,127,579	115,025,203	2,093,749,352

Anhydrous Ammonia (Manufactured at Missouri Ordnance Works; in tons)	159,171

Bag Loading (at New River Ordnance Works)	Number	Pounds Powder
Howitzer and Gun Charges	21,836,033	122,220,161
Rolled Powder Increments	239,709,092	3,373,089
Flash Reducers	84,993	
Total	261,630,118	125,593,250

Source: Dryer & Sicilia 1990:231; HPC [1945a]:36.

Mason & Hanger played an important part in the ordnance build-up during World War I. From 1917 to 1920, the firm won five army contracts, including those for construction of Camp Zachary Taylor (Louisville, Kentucky; contract signed June 20, 1917), Port Newark (New Jersey; January 1918), Port Charleston (South Carolina; April 1, 1918), Old Hickory Powder Plant (near Nashville, Tennessee; April 1918) and Gertsner (Lafayette) Aviation Field (Lake Charles, Louisiana; October 1917) (Lemert 1979:35-38). Arthur J. Sackett, Mason & Hanger's chief engineer, overwhelmed Colonel F. E. Lamphere of the Army Quartermaster Corps when he produced a complete set of progress plans for Camp Taylor overnight (Lemert 1979:35). Construction of Camp Taylor was also completed far ahead of other cantonments started much earlier. The engineering firm served as managing contractor for Camp Taylor throughout the war years. Lamphere would later state that "in seventeen years of construction work of various classes I have never been associated with a contracting firm that, in my opinion, was more efficient and desirous of serving their employer's best interest [than Mason & Hanger]" (Lemert 1979:35).

After the frantic pace of the war years, Mason & Hanger returned to conventional construction work including construction of highways, tunnels, and even a hotel (Lemert 1979:43). In 1928, the firm completed building the tower piers for the New Jersey side of the George Washington Bridge. By 1939, the firm had contracted work all across the United States. In New York City the firm was finishing the second tube of the Lincoln Tunnel; in Washington State it was erecting the Grand Coulee Dam; there were also contracts for sewer work in Boston, a Pennsylvania Turnpike tunnel, Merriman Dam in New York, and a vehicular tunnel under New York's East River (Lemert 1979:80). On many of its contracts, Mason & Hanger finished early and came in on or under budget. During the Congressional investigations into profiteering by contractors during ordnance work in World War I, Mason & Hanger was the only one not accused of such acts (Lemert 1979:38). The firm's reputation for good work on time and on budget would continue through World War II.

"In 1940 the first of several important defense contracts was signed by Mason & Hanger. Out of four ordnance plants built by the firm, Radford Ordnance Works was the first of two done on a subcontracting basis to the future operator, in this case the Hercules Powder Company of Wilmington, Delaware" (Lemert 1979:113). Other ordnance plants that were constructed by Mason & Hanger are: New River Ordnance Plant (Dublin, Virginia, January 1942); Louisiana Ordnance Works (Shreveport, Louisiana, March 1942); and Badger Ordnance Works (Baraboo, Wisconsin, January 1943).

The War Department was well aware of Mason & Hanger's abilities from its work in the earlier war. The firm also had a "cordial relationship of long standing" with Hercules, from whom Mason & Hanger had obtained the dynamite it used for years in its tunnel construction (Lemert 1979:113). Furthermore, Mason & Hanger had recently constructed Hercules' smokeless powder plant in Kenvil, New Jersey.

On September 4, 1940, Hercules and Mason & Hanger signed a subcontract for $5,317,000 for the construction of the Radford plant. Under this contract, Mason & Hanger was responsible for approximately 100 buildings, which were to be completed on an estimated schedule of ten months. The firm used the Dixie Hotel in Radford as a temporary office while an office could be constructed on the plant site (Lemert 1979:115).

Before the plant at Radford was completed, Mason & Hanger also signed a contract with the War Department to construct the New River Ordnance Plant 12 miles away. This plant would serve as the bag loading facility for powder produced at Radford. Construction at NROP was completed by January 1942. After completion of the initial phase of construction at ROW and NROP, Mason & Hanger returned to complete additions at each plant. In August 1945 the firm was involved with the construction of 12 continuous rolled powder lines at ROW when the Japanese surrendered and ended the war. Construction was halted immediately with less than 50 percent completed.

After the war, Mason & Hanger-Silas Mason Co. was designated to reactivate and operate the Louisiana Ordnance Plant and Lone Star Ordnance Plant (Texarkana, Texas) for production of ammonium nitrate fertilizer, which was in high demand in the ravaged fields of Europe (Lemert 1979:130). "Other contracts, some of which involved design and new construction as well as reactivation and operation, included Milan Arsenal, Tennessee; Illinois Ordnance Plant, Carbondale; and Ravenna Arsenal, Ohio" (Lemert 1979:130).

During the Korean War, Mason & Hanger-Silas Mason Co. rehabilitated the Cornhusker Ordnance Plant (Grand Island, Nebraska) and the Iowa Ordnance Plant (IOP; Burlington, Iowa) for return to munitions production. The firm also served as operator at the Burlington Atomic Energy Commission Plant and IOP (Lemert 1979:190).

With its World War II operations and construction management, Mason & Hanger broadened its horizons beyond tunnel and bridge construction. The firm abandoned heavy construction in the late 1950s, focusing its effort on defense plant operations. Smaller operations have also occupied the company, including water desalinization contracts with the U. S. Department of the Interior (Lemert 1979:213). Headquarters for the company are now located in Lexington, Kentucky. The company is known for pressing plastic bonded explosives, fabricating high explosives components for nuclear weapons, and assembling those weapons. Mason & Hanger continues its involvement with production of conventional ammunition and since 1951 has operated the Iowa Army Ammunition Plant (formerly IOP). Until recently the company operated the Mississippi Army Ammunition Plant (Flora, Mississippi) and the Cornhusker Army Ammunition Plant. The firm manages the Iowa Army Ammunition Plant and the Newport Army Ammunition Plant (Newport, Indiana). Just last year, the firm was awarded site management and caretaker contract for the Ravenna Army Ammunition Plant at Apco, Ohio (Lemert 1979:249-250; Mason & Hanger-Silas Mason Co., Inc., 1994:1, 5).

RADFORD ORDNANCE WORKS

Architect-Engineer Firm's Design for the Plant

The design for Radford was based on a composite of Ordnance Department specifications, Hercules' Kenvil and Parlin plants, and information known about Du Pont's smokeless powder plants (Dyer and Sicilia 1990:228); the written histories found at Radford support that assertion. There is almost no reference in these ROW histories to what role, if any, Picatinny Arsenal played in the design of Radford. There was some discussion of the influence of Picatinny in the layout of the New River Ordnance Plant, a LAP facility, which is discussed in a later section of this report. Even at NROP, however, it seems that Hercules rejected many of the Picatinny plans and layouts.

While Hercules was responsible for the design of the plant, it was still required to obtain approval of its drawings from the government. Hercules' drafting department prepared all drawings pertaining to the design of the plant, including the general building layout and construction documents (Serrum 1941:325). A completed drawing was checked by several people within the drafting department before it was sent to the office of the Ordnance Department and the Constructing Quartermaster, War Department, in Washington, D.C. (Serrum 1941:327). The drawings were approved for construction, recorded, and turned over to a clerk for blueprinting (Serrum 1941:327). Prints of approved drawings were sent to Radford Ordnance Works, File Order Department, and the War Department at Washington, D.C., Reference and Purchasing Department (Serrum 1941:328).

With the explosion at the Kenvil plant, the plans for ROW were extensively redesigned. While Hercules provided the main design work, it is apparent that Mason & Hanger's design staff also played a major role in designing the new plant. "From the design drawings furnished by Hercules, the Mason & Hanger design

staff detailed and elaborated plans for the production and other buildings, which generally were of cinder block construction, with concrete foundation walls and floors and wood frame roofs" (Lemert 1979:115). Table 2 indicates the number of drawings involved in the construction of the plant.

Table 2
Approved Radford Ordnance Works Drawings

Areas	Active	Void	Canceled	Total
Smokeless	558	20		578
Nitrocotton	402	29		431
Acid	327	11		338
TNT	314	33		347
Power & Water	259	11		270
General	245	20		265
Administration	201	6		207
Pilot Plant "A"	196	31		227
Pilot Plant "B"	172	9		181
Rolled Powder	154	22		176
Pentolite	149			149
Double-base	147	6		153
Shops	60	1		61
Cannon Range	56	2		58
Laboratory	49			49
Magazine	12			12
E. C.			24	24
Virginia Ordnance			93	93
Total	3,301	201	117	3,619

Source: HPC [1945a]:73

As a rush job, it seems inevitable that design would have become a team project. The following incident, recounted in a Mason & Hanger history, indicates the hurried pace of the construction at Radford:

> . . . drawings were often incomplete when they reached the Mason & Hanger design staff. One morning Graddick (Mason & Hanger office engineer) told a newly hired engineer to prepare a material takeoff on a drawing of a building in the barracks complex. The takeoff was to include the amount of all materials needed to complete the entire structure, but the drawing showed only one section of it. Anticipating the newcomer's reaction, Graddick added, "Don't ask for any more drawings; there aren't any" (Lemert 1979:116-117).

Type of Construction

Designs for the early GOCO plants were based on using permanent construction methods. However, with cost overruns mounting, the Chief of Ordnance ordered a switch from permanent (25-year) construction to temporary (5-year) mobilization construction on January 18, 1941. Amenities such as tile in bathrooms, slate roofs, and air conditioning were the first to go. The Administration Building could be no more than one story and not of brick. For those plants, such as Radford, that were already under construction, the choice of the buildings to be switched from permanent to temporary construction was left to the QMC's discretion. By March 1941, the Secretary of War ordered that standardized plans be used for all properties except manufacturing buildings (Kane 1995:84).

The original three lines for the manufacture of smokeless powder at ROW were designed to be in buildings of permanent construction (HPC [1945]a:57). These buildings were constructed with 10-inch monolithic foundations with spread concrete footings. The foundation wall was carried six inches above the floor line with side walls framed with 2-x-6-inch wood studs on two-foot centers and enclosed with corrugated asbestos or corrugated steel. Combined Shops and Solvent Stores were constructed with side walls of brick or concrete block. Wood rafters on two-foot centers were used in roof construction and sheathed with $^{7}/_{8}$-inch tongue and groove lumber and covered with 20-year composition or corrugated steel roofing. Doors and windows were of standard design that could be furnished by any local mill. Where operations necessitated, the buildings were lined with plywood, masonite, or transite, and the floors were finished with nonconductive or acid-resisting surfaces (HPC [1945]a:57).

The main power house was skeleton-framed of steel with concrete foundations and column footings. The operating floors were structural-concrete slabs and the platforms were built up of steel grid. The walls were brick and the roof was precast concrete slab covered with 20-year built-up roofing. Factory-type steel windows and doors were used. The nitrating houses were constructed similarly to the main power house. Other buildings that required heavy framing because of the loads of equipment to be supported were found in the acid area and included the Nitric-acid Concentrator, Oxidation House, and Compressor House (HPC [1945]a:58).

In its history of the Radford Plant, Hercules notes that "when the increases were made, including Pilot Plants A and B and the Pentolite Area, the type of construction was changed to that of a more temporary nature" (HPC [1945]a:61). Buildings of temporary construction had eight-inch concrete foundation and concrete first floor slabs poured directly on grade. Side walls were built with 2-x-6-inch studs, on two-foot centers and faced on the exterior with novelty siding, a type of weatherboard siding popular in the early twentieth century. Roof construction switched to using class-B rolled type finished roofing. Buildings were no longer lined and asphalt tile was substituted for rubber floors. The use of corrugated asbestos, corrugated steel, and metal roof ventilators was also discontinued. Novelty siding weatherboard was used in place of corrugated sidings and reinforced concrete was kept to a minimum.

The Horseshoe Power House was designed using temporary construction methods. The foundations and first-floor slab were of concrete. Side walls were of concrete block with brick piers for rafter supports. A 10-year built-up roof was substituted for a 20-year roof and wood factory sash was substituted for that of steel.

Architectural Style

The design of the Radford plant is strictly utilitarian and is a good example of the modernist theory "form follows function." Most buildings are simple, gable-roofed structures with little attention to ornamentation or stylistic detailing. The Administration Building is concrete block with a gable roof as are many of the support buildings such as the hospital and barracks. The only structures with brick cladding are the main power house, shop structures, and the change houses in the earliest built sections of the plant. Many of the

buildings in the process areas are wood frame and originally had asbestos siding. Recently, some buildings have had the exterior siding removed and the exposed frame sprayed with insulating foam. This precludes wall cavities where nitrocotton can build up and cause explosions.

Plant Layout

The ROW is divided by the New River into two sections: the main plant area on the south side of the river, and magazines and cast propellant within the famous Horseshoe Bend of the river. The main manufacturing site was laid out around the main power plant that provides both electricity and steam. In the same immediate area are situated the Administration Area, Acid Area, and Shops Area with production area to the north (Figure 3). The 1984 HABS study gives a detailed account:

> The Acid Area originally included facilities for manufacturing nitric acid (Buildings 702, 703) and concentrating sulfuric acid (Building 704). The administrative compound contained the old Main Administration Building (Building 200), Telephone Exchange (Building 263), Hospital (Building 205), and similar support facilities. The Shops Area contained a large Combined Shops structure (Building 500) and numerous other small specialty shops and storage facilities. The smokeless powder manufacturing facilities were constructed in three parallel "lines" (A, B, and C) between the power plant and the river (MacDonald and Mack 1984:20).

Continued construction throughout the war was designed to adjoin the original area. The nitroglycerin (Buildings 3614-3638), TNT (Buildings 4500-4510), and First Rolled Powder (Buildings 3700-3749) areas were built to the west while the Pentolite Plant (Buildings 4000-4020) was located to the east. Toward the end of the war two areas for increment packaging were begun—one to the west (Buildings 7104-7220) and one to the east (Buildings 9309-9378)(MacDonald and Mack 1984:21).

The buildings at Radford reflect the manufacturing processes that took place within them. Certain processes were grouped together in a set of buildings. For example, highly inflammable materials were grouped together in the Cotton Area. Buildings that housed explosive materials employed two different types of construction. They either were widely spaced and barricaded, or incorporated "blow out" construction.

Barricaded buildings were used in the Solvent Recovery Area (series 1600 buildings) and in the Finishing Area (series 1700 buildings). Barricades were built of heavy timbers with a screened dirt fill to a five-foot thickness and were as high as the building (MacDonald and Mack 1984:21). Blow out construction used light-weight panels that would blow out with a change in interior air pressure and were designed to control the direction of an explosion rather than contain it. These include buildings in the Powder Area—1500, 2500, and 3500 series buildings (MacDonald and Mack 1984:21).

Changes in Designs

The original cost of the Radford Plant was estimated in June and early July 1940 before any plans or specifications were made and without any knowledge of the exact site of the plant. Costs were based on the Hercules plants at Kenvil and Parlin with the assumption that the same type of construction and design would be used and that the terrain would not be more difficult than that at Kenvil and Parlin. At those plants, land was comparatively flat and the plants compact.

The explosion at Hercules' Kenvil plant caused a major rethinking of the plans for the Radford plant. Prior to that disaster, it was thought, based on past experience and tests, that even in large quantities smokeless powder would burn without exploding. Safety measures were adopted to prevent fires and to control them once started, but there was no expectation of an explosion. On September 12, 1940, a fire and subsequent

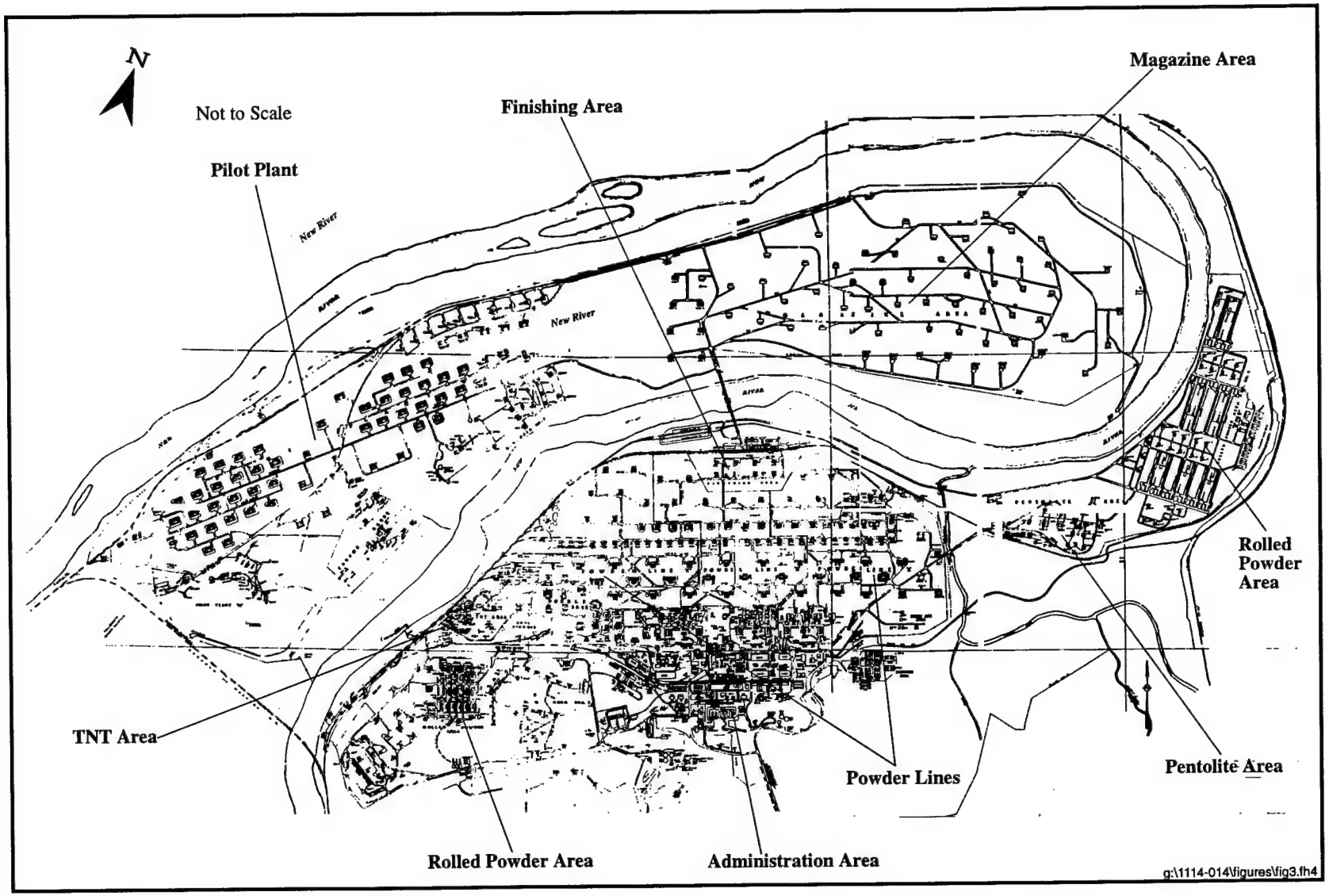


Figure 3. General plat map of the Radford Ordnance Works (1941 HPC Drawing #M599).

explosion in the Solvent Recovery buildings at Kenvil entirely obliterated those buildings (ground zero of the blast) and completely destroyed all buildings within a radius of 600 feet with the exception of one building protected by a barricade. This explosion indicated that smokeless powder, in bulk and unconfined, presented an explosion hazard while burning. This disaster completely changed the treatment of smokeless powder and necessitated the redesign of the solvent recovery process as well as providing much greater distances between buildings for safety.

Revision of Radford's layout was essential. The original contract called for a two-line powder-producing facility with provision for six lines, if needed. Revised plans, however, called for increased distance between operations and, thus, Radford became a three-line operation (HPC [1945]a:66).

The solvent recovery process was redesigned so that the two processes of solvent recovery and water-drying were performed in separate buildings. Each solvent recovery tank was located in a room separated from its neighbors by reinforced concrete walls. Special automated sprinklers inside the solvent recovery tanks were designed so that, in case of fire, not only the burning tank, but all others in the building would be deluged. "The buildings were then barricaded and spaced one from the other at 330'" (HPC [1945]a:69-70). The new design of the plant called for 27 Solvent recovery Houses and 27 Water Dry Houses, instead of the original nine solvent recovery houses that combined the two processes. Other changes included construction of four additional rest houses; additional dehydrating presses; the separation of finishing press and cutting houses; and an increased size in the water storage, pumping house, and filter plants (HPC [1945]a:70).

The original plans called for quickly building permanent warehouses and using them for construction work. Because new plans and designs for these warehouses had to be drawn, the warehouses could no longer be used for construction purposes and a large number of temporary buildings had to be built to house the contractors, construction forces, and government employees. Redesigning the plant also necessitated moving the Cotton, Powder, and Magazine areas and relocating the office and administrative areas. The newly chosen areas were much more hilly and required more grading. In fact, a much larger area of the plant than previously planned had to be built in the hills, considerably increasing the cost. Using the Horseshoe area also meant building a bridge across the New River.

The enlarged plant area meant more roads and parking facilities, longer and larger sewer, water, and steam lines as well as longer telephone and power lines. The redesign also eliminated tram equipment in favor of roads and trucking equipment (HPC [1945]a:70). A letter dated June 13, 1941, from then assistant manager A. Van Beek to Lieutenant Colonel Serrum details the information relating to changes in the plant plan due to the tragedy at Kenvil (HPC [1945]a:73).

It is clear from the historical documentation kept by Hercules at the Radford Plant that it felt one of its biggest innovations from the design standpoint was the main rolled powder building in addition to rolled power production. The history notes, "the efficiency of 'straight-line' production has been accepted in industry for some time. However, this was probably the first time in the explosives industry that 'assembly-line' features were incorporated into the design of a single building to include operations which had formerly been done in several buildings. Powder to be 'reworked' was the only reversal of flow in the production line" (HPC [1945]a:80). Incorporated into the new design for the Rolled Powder Building were the Pre-roll, Rework, Final-roll, Sizing-roll, Sewing and Utility, Slitting, Punching, and Sorting sections. Prior to this design, inclement weather presented an operation problem when powder had to be transferred between buildings. Efficiency of operation and safety were significantly increased and considerable savings were incurred on road construction (HPC [1945]a:80).

The difference in layout between what is now known of as First Rolled Powder, located in the western end of the plant, and Fourth Rolled Power in the eastern end, illustrates this changed in design. First Rolled Powder is laid out in what could be called a haphazard fashion with buildings scattered across an open area.

In Fourth Rolled Powder, however, each line is housed in long, straight buildings. The structures combine several functions into a single building with sections separated by passageways and concrete fireproof walls.

Main Construction Phase

Immediately after Hercules signed the contract for ROW, Constructing Quartermaster then Captain Floyd L. Strawn issued verbal instruction to the contractor to begin construction. R. R. Veale, the first of the Hercules Powder Company supervisors, arrived in Radford just days later. From September through November 1940, Major Floyd L. Strawn was the commanding officer at the Radford site. On November 2, 1940, Lieutenant Colonel Mark M. Serrum assumed command of the ROW (Baldwin 1942:208-209) and it would be under his command that ROW would complete its initial construction phase.

Construction at ROW began on September 6, 1940 (Baldwin 1942:207). Estimates had put completion of the first smokeless powder line at 10 months. The construction subcontractor, Mason & Hanger, however, was urged on through competition with the Du Pont company, which was building its Charlestown plant, and by Hercules' need to replace its Kenvil plant, which exploded on September 12, 1940. This tragedy seriously curtailed powder production and increased the need to provide powder facilities. Hercules succeeded through Mason & Hanger's tremendous efforts and ROW was dedicated on March 14, 1941, three months ahead of schedule (Baldwin 1942:212), and before Du Pont's plant was ready. Upon completion and prior to the buildings being put into operation, they were transferred to the Ordnance Department and the operating contractor for initial acceptance of the construction. Smokeless powder was produced for the first time on Line "A" on April 5, 1941.

Construction was far from complete, however. Mason & Hanger's work force continued to grow, reaching its peak employment on March 15, 1941, with 23,150 employees (Baldwin 1942:212). This figure did not include the number of government personnel at the plant. The average employment level for Hercules and Mason & Hanger staffs together during construction was 10,353 (HPC [1945]a:195). With partial completion of the plant, the third shift was closed down on March 30, 1941 (*RPW* 1941d:1). As work on the plant continued, the construction work force declined while the operations work force grew. In September 1941, little work remained to be done (approximately $200,000 worth) and Mason & Hanger requested release to continue work elsewhere. Hercules completed the remaining construction (HPC [1945]a:182-183, 197). By January 15, 1942, after completion of the first phase of construction, construction forces reached a low of 758 (HPC [1945]a:198). Recruitment efforts started as additional work was requisitioned and a new peak was reached on September 1, 1942, with 4,387 employees (HPC [1945]a:198). On July 1, 1943, with the second phase of construction completed (including the Pentolite Plant), the construction forces ceased to exist as the Plant Engineering Department took over alteration and modification work (HPC [1945]a:184).

Construction at Radford continued steadily throughout the war. By December 15, 1941, all originally contracted construction under W-ORD-462 and Supplements 2, 3, 4, 5, and 6 was complete with the exception of the Pentolite Plant, for which Hercules had signed a contract on September 9, 1941 (Anonymous n.d.a:22; Baldwin 1942:125, 226). At that time there were 667 buildings and structures on the reservation (Serrum 1941:729). Although originally estimated to cost $25 million, the actual cost of the plant was $51,808,221 with over 1,000 buildings on the site (Baldwin 1942:24). Table 3 shows the original contract with supplements, what they required, and the costs.

The success of this period is due to the integration of skills among the Hercules, Mason & Hanger, and War Department staffs. This integration was not without setbacks, however. Conflicts arose between the construction crew, which was operating in a rush job situation, and the lower-ranking Army officers who "appeared more bent on watching for minor infractions than on speeding the work by helping the contractor surmount the snarls of red tape" (Lemert 1979:115). Mason & Hanger's general manager on the site, Robert

Table 3
Original Contract for ROW and Subsequent Changes

Number (Estimated Cost)	Date	Work contracted
Contract W-ORD-462 ($24,975,588)	August 16, 1940	To design, construct, equip, and operate a plant for a plant for nitro-cellulose smokeless powder.
Supplement #1 ($9,983,483)	September 21, 1940	To increase capacity of plant to 300,000 lbs/day.
Supplement #2 ($1,969,000)	November 18, 1940	To manufacture extruded double-base and rolled strip double-base powder.
Change Order A ($63,750)	August 20, 1941	To provide for the addition of a pulp dry house on "A" line; to switch from cotton linters to wood pulp.
Supplement #3 ($1,286,170)	September 9, 1941	To construct, equip, and operate a Pentolite plant.
Change Order B ($28,581)	October 4, 1941	To add buildings and equipment necessary for a 20-mm Ballistic Range.
Supplement #4 (no allocation)	December 16, 1941	To extend operations of plant for another 12 months.
Change Order C ($1,320)	January 1, 1942	To construct one igniter magazine.
Supplement #5 ($10,536,916)	February 25, 1942	To add facilities for TNT manufacture; increase smokeless production to 425,000 lbs/day; provide Pilot Plants for Special Powder A and Special Powder B; and to operate Virginia Ordnance Works.
Supplement #6 ($963,413)	July 28, 1942	To increase smokeless production to 450,000 lbs/day; to increase TNT capacity; to add 9 TNT magazines; to add 16 smokeless magazines (at NROP); to provide for changes in Pilot Plant A, additions to rolled strip powder; and to eliminate operations for VOW.
Supplement #7 ($4,625,110)	December 1, 1942	To construct oleum plant; provide for addition to Special Powder B line; increase production of Special Powder A; increase rifle powder production; provide for production of rolled sheet, Navy double-base powder, and Research and Development and experimental work.

L. Telford, informed Hercules general manager Bill Ellis of the situation. Ellis arranged for a visit from General Levin Campbell, Chief of Army Ordnance. Addressing the assembled staffs, the General stressed the importance of finishing the plant as quickly as possible. He stated that the officers for Mason & Hanger were not to be reprimanded for minor mistakes. "'Furthermore,' the general said, 'if the work was hamstrung by delays caused by lack of cooperation'—he paused, and Ellis completed the statement by drawing a finger across his throat to indicate the consequences" (Lemert 1979:116). The meeting had the desired effect and the project was finished ahead of schedule (Lemert 1979:116-117).

Subcontracts

Mason & Hanger of New York served as the general construction subcontractor, having signed a contract with Hercules on September 4, 1940 (Baldwin 1942:207). This contract was based on a cost-plus-fixed-fee, with the estimated cost of the project set at $5,317,000 and the fixed fee set at $202,000 (Baldwin 1942:107). This contract stated that along with offices and administrative buildings, the subcontractor was also responsible for: general clearing and grading; temporary construction buildings; all construction tools and equipment; buildings in the Power Area; Shop and Storehouse area; the nitrating houses; outside water, electric, and sewer lines and houses in the "Village," which were rented to Hercules officials and Army officers (Baldwin 1942:114-116). Before termination of the subcontract in October 1941, the company had produced $23,617,470.38 worth of construction (Anonymous n.d.a:17).

The architectural firm of Carneal, Johnston & Wright of Richmond, Virginia, was awarded a subcontract "to perform all architect-engineer services for the construction of Radford Village" (Anonymous n.d.a:17). These were houses for plant workers that were located within the city of Radford. This included preparing necessary designs, drawings, and specifications for 100 units. The number of houses built was later reduced to 43 residences and 13 garages. Construction was started on these houses by Mason & Hanger on June 13, 1941.

Beyond these major subcontracts, Hercules let other contracts on "grading, sewerage and water lines, power lines, telephone lines, fencing, installation of machinery, sprinkler system, and a large number of smaller subcontracts" to approximately 60 companies (Baldwin 1942:12). Operation of the cafeterias and mess halls, storage, supply of production materials, and removal of a cemetery on the property were also subcontracted (Anonymous n.d.a:Appendix). These subcontracts were let on both a fixed fee and lump sum basis to companies from as far away as Chicago, Cincinnati, Philadelphia, and New York City, as well as companies from Roanoke and Christiansburg.

The project required a large amount of machinery and earth moving equipment. According to contract specifications, the supply of equipment was Mason & Hanger's responsibility. In August 1940 the Blue Ridge Parkway project, undertaken by the WPA, was declared nonessential. Mason & Hanger was able to obtain the equipment used on that project from the supplier, Ralph E. Mills of Frankfort, Kentucky (Lemert 1979:114). On average, 964 units of equipment were used on site; this figure reached its zenith the week of February 21-28, 1941, when 1,510 units were used (HPC [1945]a:192-193). This equipment included trucks, air compressors, grading equipment, cranes, and welding units.

Temporary electric power for construction was supplied through Appalachian Electric Power Company (ApCo) until the plant power house was completed (Anonymous n.d.a:19). The permanent electrical system at the plant was powered by four Allis-Chalmers turbine generators, each with a 6,000-kw capacity (Anonymous n.d.a:24). Afterwards, the temporary 3000-KVA power hook-up supplied by ApCo was used as a stand-by supply. In 1949, ApCo took over operations at the power house for the plant.

Both the Norfolk and Western Railway Company (N & W) and the Virginia Railway Company signed subcontracts with Hercules to construct rail lines within the plant as well as connect the plant with existing

lines. On September 4, 1940, the N & W agreed to construct a spur track from the main line to the plant site (Baldwin 1942:117). Upon completion, the railway would receive $55,550 for construction of 2.6 miles of track, including "three turnouts on land of the Powder Company near Pepper" (Baldwin 1942:117). The Virginia Railway Company also built a track spur into the plant area. This subcontract, for the lump sum of $63,000, was signed on January 4, 1941, and the work was completed on March 10, 1941 (Anonymous n.d.a:Appendix).

Rail tracks were laid throughout the plant by both N & W and Virginian railroads. Incoming freight could easily be deposited at the location it was most needed. "Much of this temporary trackage remained as part of the permanent railway system of the plant" (Anonymous n.d.a:19). Fifteen miles of track were constructed throughout the plant and were connected to both railroads. The railroad brought in the lifeblood of the plant—workers and materials. During the first five months of 1941, N & W estimated that it had carried 1,020,144 workers one-way from Roanoke, Bristol, Bluefield, and intermediate stations to ROW (Baldwin 1942:217). By December 18, 1941, 27,921 railroad carloads of bulk materials had been received at ROW and by June 23, 1943, shipments totaled 48,075 carloads (Baldwin 1942:226; HPC [1945]a:194). Approximate quantities of these materials in 1943 statistics (HPC [1945]a:193-194) include:

Cement	168,285 bls.
Sand	54,921 tons
Stone	109,842 cu. yards
Lumber	23,023,800 bdft
Reinforcing steel	2,825 tons
Structural steel	4,930 tons
Plat steel (tanks, etc.)	3,573 tons
Steel pipe	6,814 tons
Cast iron pipe (2" to 18")	7,149 tons
Duriron pipe (4")	42 tons
Fittings (for steel, black steel, cast iron, wrought iron, wrought steel, and Duriron pipe)	7,899 tons
Chrome pipe & fittings	192 tons
Chrome plate (tanks, etc.)	259 tons
Copper sheet	206 tons
Copper wire	100 tons
Galvanized sheet and corrugated metal	610 tons
Lead	900 tons
Concrete pipe	3,835 tons
Terra cotta pipe	5,185 tons
Excavation and grading	2,803,066 cuyd

Water was brought to the plant by tank truck from Radford and temporary sewers were installed. Temporary steam for the cotton line was supplied by a locomotive rented from N & W (Anonymous n.d.a:21). Steam was later supplied by five combustion units. The permanent main plant water supply at the pumping station consisted of four units, one of which was retained for emergency. The three units in operation had a maximum capacity of 38,880,000 gallons per 24-hour day (Anonymous n.d.a:22). Water was filtered through chemical treatment and a sand filter. Raw, or untreated, water was used for fire and cooling purposes. Water in the Horseshoe area was supplied by a well, providing 214,000 gallons per day (Anonymous n.d.a:23). Steam in the Horseshoe area was supplied by six Babcock & Wilcox boilers (Anonymous n.d.a:23). A sewage treatment plant was built on the reservation with a capacity of 1,500,000 gallons per day and served the entire plant, except for the Pentolite and Magazine areas systems, which empty into septic tanks (Anonymous n.d.a:24).

Problems and Delays During Construction

Accidents and weather were the major causes of delay in this initial construction period. On December 19, 1940, ROW suffered its first fatality when Walter S. Doyle, a laborer, was struck and killed by a train at a railroad crossing. On February 23, 1941, William Allen Rhodes, electrician, fell from a pole in the Powder Area and was killed (Anonymous n.d.a:27). During 31 million hours worked during construction, there were six deaths at ROW. Overall, however, operations at ROW were very safe and the plant would go on to win five Army-Navy "E" awards, in part because of its safety record (*RPW* 1945h:2).

The weather conditions for the construction period were fairly poor for the first few months. Not unusual to the New River valley, the winter was very cold with high winds and resulted in occasional work stoppages. During the fall and spring rains, the newly dug earth turned the work site into a muddy bog causing the equipment to become mired on the temporary roads (Anonymous n.d.a:21). A snow storm in March 1942 suspended work for about three days and the drifted snow caused traffic congestion (Anonymous n.d.a:22).

To combat the problem of transporting labor supply into the area, Hercules chartered special trains from Roanoke, Wytheville, and Bluefield to run to the plant. There were special bus runs as well. Although 350 men had been drafted from the Hercules staff by August 1941, the draft was not a cause of a labor shortage until much later in the war (*RPW* 1941d:1). There were few labor disputes during this construction period. One incident in 1941, however, concerned electricians who threatened to walk off the job, and in May 1943 steam fitters were called off the job by the Roanoke local union (HPC [1945]a:210).

Other causes for delays in construction at ROW were similar to those at other ordnance work projects. "The important delaying factors were: getting the required drawings and layout of buildings to the plant site when needed; the placing of orders for and the delivery of materials and equipment at the plant by the time they were needed; and during the early stages, the shortage of the proper construction equipment" (HPC [1945]a:198). The rushed nature of the work resulted in revisions to structures sometimes even as they were being built; for Hercules engineers would turn over drawings to the construction supervisors in the morning and by the afternoon, foundations and framing were completed (Lemert 1979:116). An additional frustration was that the drawings were often incomplete when they reached the Mason & Hanger staff.

Extent of Wartime Construction

The breadth of the initial construction project is difficult to grasp. Amazing statistics were reported in the plant newspaper such as the number of telephone calls made from the plant in a week or the amount of mail delivered. By September 1941 an estimated 163,000 cubic yards of concrete had been poured at the site—enough to construct a road 20 feet wide, eight inches deep and 62 miles long (Baldwin 1942:218). Approximately 49.7 miles of road, of varying widths, were constructed at ROW. In addition, almost 85,000 square yards of parking area and aprons were constructed (Anonymous n.d.a:25). By mid-1941 little remained of the farm fields that had existed on the site a little over a year earlier (Plates 1a-c, 2a-b).

As if in awe of themselves, the plant newspaper ran an article with photographs of the original land exclaiming "Miracle of Transformation Revealed by Plant Pictures" (*RPW* 1941g:1). The photographs were taken by Hercules engineer Joe Hoskins in October 1940 and show rolling hills and a temporary shack used by the engineers as headquarters during that time. The plant's rapid construction appears to be a result of skilled leadership and inspired by patriotism (Table 4). Noting how quickly all this had happened, the plant newspaper article marveled, "It doesn't seem like the plant could have been what it was then, does it? Not when you know what it looks like today" (*RPW* 1941g:1).

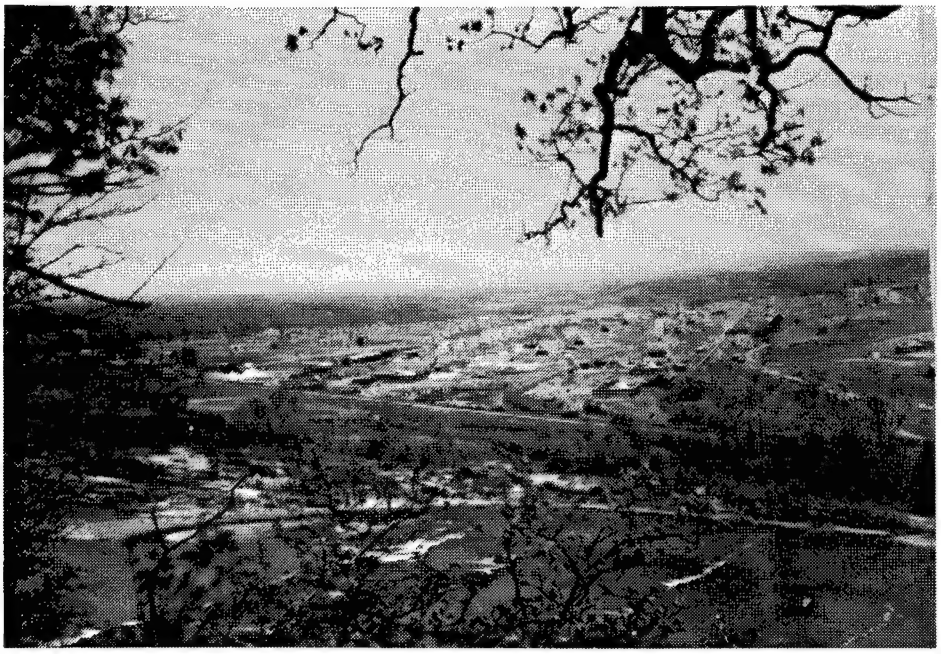


Plate 1a. Radford Ordnance Works, from across the New River and north of the Pumping Station, looking south, May 26, 1941.

Plate 1b. Radford Ordnance Works, from across the New River, showing west end of "C" line (rear) and lower thoroughfare (foreground), looking south, May 26, 1941.

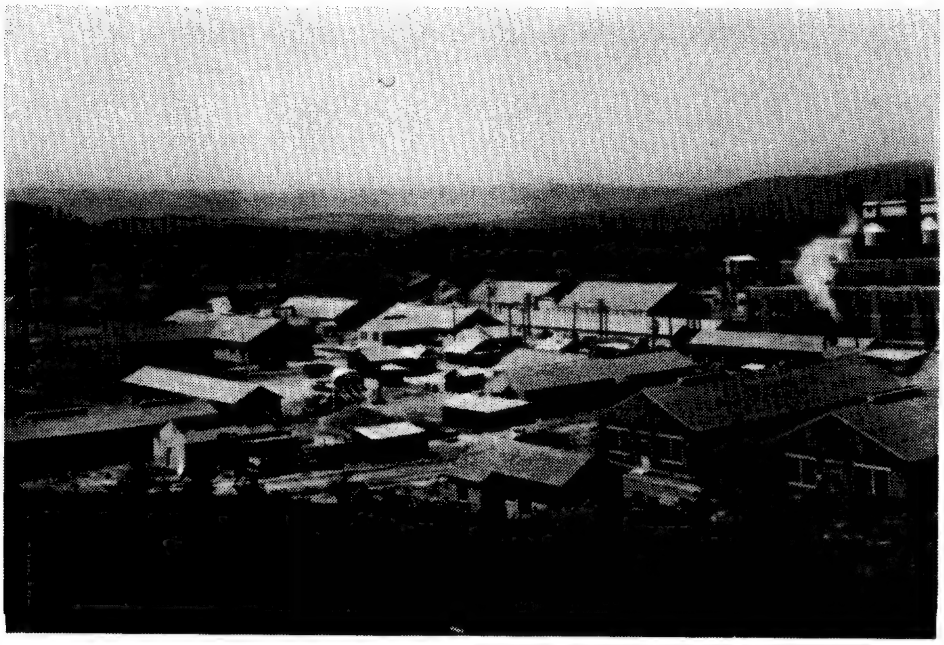
Plate 1c. Radford Ordnance works, from across the New River, showing the river Pumping Station (center foreground) and a portion of the Rolled Powder Line (center left), looking south, May 26, 1941.

Continuation of Construction at ROW During the War

Construction occurred at Radford in several phases. By early September 1941 the first phase of construction was largely complete and Mason & Hanger was released from its contract on September 8, 1941. The remaining construction work would be completed by the Hercules construction forces (HPC [1945]a:197). As the first phase of construction was completed, additional projects were received. In mid-September 1941 the order to build a pentolite plant capable of manufacturing 10,000 pounds per day was received. The construction work consisted of two pentolite houses, two neutralizing houses, acetone recovery buildings, refrigeration and storage building, four dry houses, one pack house, two warehouses, office, laboratory, change house, gate house, TNT storage, and several small buildings. The work was begun October 1 and was completed and transferred to the Operating Department on March 9, 1942.

Another project, begun January 20, 1942, was a two-line TNT plant with a completion date of July 1, 1942. A crew of approximately 400 men worked on this project. Materials were difficult to obtain given the considerable number of acid plants then being constructed throughout the country. Experience gained at Volunteer Ordnance Works about TNT was used at Radford. After completion, the TNT plant was placed in stand-by (HPC [1945]a:202).

On March 6, 1942, instructions were received to construct Pilot Plant "A" for the manufacture of rocket powder (HPC [1945]a:203). Construction was begun immediately on the site in the Horseshoe area near the Norfolk & Western tunnel (HPC [1945]a:203). Then in May 1942, construction began on Pilot Plant "B" for the manufacture of double-base powder (HPC [1945]a:204). This work necessitated changes in the smokeless powder C-line as well (HPC [1945]a:204).



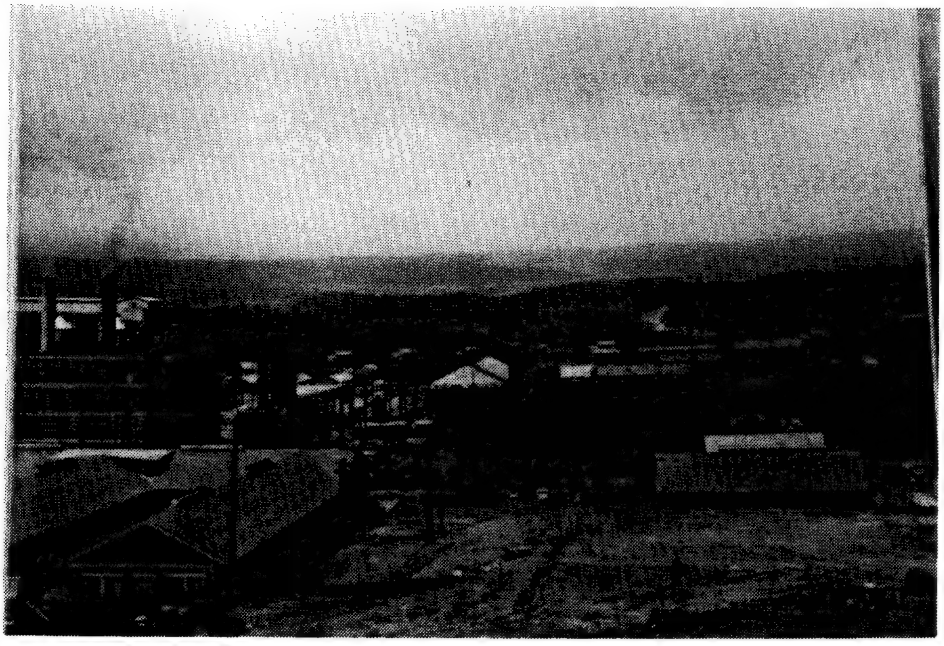


Plate 2a, b. Views of Radford Ordnance Works looking north, April 26, 1941.

Table 4
Construction Units at Radford Ordnance Works

Area	Process	Storage	Service	Total
Office & Administration Area			53	53
Staff Houses			16	16
Radford Village			44	44
Ballistic & Cannon Range Area	6	6	1	13
Shops & Stores Area			19	19
Acid Area	10	7	13	30
Cotton Line "A"	19	7	7	33
Powder Line "A"	84	19	29	132
Cotton Line "B"	19	4	2	25
Powder Line "B"	58	18	18	94
Cotton Line "C"	19	8	4	31
Powder Line "C"	57	11	32	100
Magazine Area				
Small Arms		38		
Cannon Powder		38		
Pentolite		4		
Magazines (New River)		59		124
Double-base Line	39	8	8	55
Rolled Powder Line	43	2	16	61
Pentolite Area	17	5	5	27
Power & Water Area	6	17	5	28
TNT Area	23	14	6	43
Pilot Plant "A"	27	3	7	37
Pilot Plant "B"	76	4	19	99
Total	503	257	304	1,064

Source: HPC [1945a]:193-194

In early May 1942, plans were received for additional powder production facilities that would increase smokeless powder production by 150,000 pounds per day. This planned construction was scattered throughout the entire plant and included an addition to the main power house and doubling the size of the acid plant (HPC [1945]a:205). Plans for the construction of an additional 15 magazines in the Horseshoe area were received on May 22, 1942. Rapid progress was made on the magazines and they were completed at the rate of one magazine each day and a half (HPC [1945]a:207-208). By this time construction crews had expanded from 500 men in the fall of 1941 to almost 5,000. Most of the workers were obtained from the region (HPC [1945]a:207).

The Rolled Powder Area at ROW, a unit of the Smokeless Department, was the largest plant of its kind in the United States (HPC [1945]a:1183). Ground was broken for the plant in April 1941 and construction consisted of 44 operating buildings, a maintenance shop, and an area office (HPC [1945]a:1183). This first phase of construction was completed in January 1942 and comprised four and one-half operating lines (HPC [1945]a:1183). Rolled powder operations began on October 1, 1941 (HPC [1945]a:1184).

On May 22, 1942, plans were received for the construction of an addition to the Rolled Powder Area as part of the second phase of construction at ROW (HPC [1945]a:207). This construction consisted of additions to some of the original rolled powder buildings as well as new buildings required for production increases and safety reasons (HPC [1945]a:1183-1184). All additional construction in the area was completed by November 1942 (HPC [1945]a:1184).

The Phase Two construction work at ROW was completed by Hercules Powder Company on July 1, 1943, and included the construction of a diversion dam on the New River to control the rate of flow at the pumping station (HPC [1945]a:208). When Phase Three began in January 1944, it was contracted to Mason & Hanger Company who had done the original construction work. Design plans would continued to be handled by Hercules (HPC [1945]a:211).

In January 1944, the third phase of construction began for "the purpose of expanding the facilities for the production of trench mortar powder" (HPC [1945]a:1275). Two units or lines were completed in August 1944 and a third line was completed in February 1945 (HPC [1945]a:1275). One of these lines was built to the west of the earlier rolled powder development (Buildings 7104-7220) and two were built to the east (Buildings 9309-9378) (MacDonald and Mack 1984:21).

A fourth line or unit was authorized in 1945 and called for additional facilities for the manufacture of 1,200,000-1,500,000 pounds of double-base trench mortar powder per month (HPC [1945]a:214, 1276). The facilities consisted of 12 continuous rolled powder lines, each line contained in a building approximately 900 feet long. Construction of this unit, located to the northeast of the Pentolite Plant, was begun in February 1945 (HPC [1945]a:1276). Both the scarcity of common labor and jurisdictional disputes and strikes held up completion of this project. Construction was less than one-half complete when discontinued on August 13, 1945, with the end of the war (HPC [1945]a:1276). The partial construction is still standing at the plant as it was left 50 years ago.

The Rolled Powder Area was divided into two areas during 1945 for managerial purposes (HPC [1945]a:1276). Rolled Powder Area No. 1 consisted of the original production facilities plus the two additions completed in August 1944 (HPC [1945]a:1276). Rolled Powder Area No. 2 consisted of an addition completed in February 1945 and Buildings 7113, 7800, 7801, a 4.2-inch Chemical Mortar Increment Manufacturing Line, and an Increment Salvage Building (HPC [1945]a:1276). Today, these areas are referred to as First Rolled Powder located in the western part of the reservation and Fourth Rolled Powder located in the northeastern part of the reservation (Charles Flynn, interview 1995).

In November 1944 work on the construction of an increment packaging plant began at Radford. Heretofore, increment packaging had been done at NROP. Although held up by labor problems, work was completed in May 1945 (HPC [1945]a:213).

Contractor Operations

As noted above, Hercules' contract called for both the design and construction as well as the operation of the plant. At GOCO plants, the plant manager was the contractor's representative in the execution and administration of the contract and all transactions between the War Department and the contractor were carried on between the commanding officer and the plant manager.

The dedication ceremonies, held on March 14, 1941, officially recognized the plant as ready for operation, although because of delays in receiving equipment, actual production did not begin until April 5 (Table 5). Prior to November 1, 1941, H. V. Chase had been the plant manager with A. Van Beek as assistant manager. After that date, with most of the original construction work complete, Mason & Hanger was released from its contract and Van Beek became the plant manager. Because of the dual nature of Hercules'

Table 5
Start-up and Shutdown Dates of Production Areas at ROW

Area	Initial Start-up Date	Shutdown at End of WW II
Single-base powder		
A line	April 5, 1941	July 31, 1945
B line	June 20, 1941	August 27, 1945
C line	September 10, 1941	August 27, 1945
Double-base powder		
C line	September 24, 1941	September 11, 1945
Acid	June 6, 1941	August 10, 1945
Nitrocellulose		
A line	July 5, 1941	July 31, 1945
B line	June 17, 1941	August 27, 1945
C line	September 8, 1941	August 31, 1945
Nitroglycerine	September 26, 1941	August 27, 1945
Rolled Powder		
Area No. 1	October 1, 1941	September 21, 1945
Area No. 2	August 8, 1944	September 18, 1945
Pentolite	March 24, 1942	August 17, 1945
Oleum	April 22, 1943	August 11, 1945
Solvent Recovery	April 1, 1941	September 11, 1945
Solvent Area	July 14, 1941	September 14, 1945
Finishing Area	April 21, 1941	September 19, 1945
Pilot A line	June 15, 1942	October 5, 1942
Pilot B line	October 24, 1942	September 28, 1945
Increment Packaging	June 27, 1945	August 20, 1945

contract for ROW, there was not a major break between the administration of the architect/engineer and the contractor.

Cost-Plus-Fixed-Fee Contract

The cost-plus-fixed-fee (CPFF) was a method of contracting that was widely used during World War II. In cost-plus (CP) contracts the group letting the contract, in this case the government, would pay for all the contractors' costs plus additional monies (the fee) to allow the contractor a profit. A similar type of contract,

the cost-plus-a-percentage-of-cost (CPPP) contract, used during World War I was widely unpopular because it proved to be an incentive for abuse. Contractors would pad their expenses to increase the fees paid them.

The problems incurred using the CPPP-type contract made the use of the CPFF-type contract difficult. Proponents felt that some type of guaranteed profit was necessary to lure business into this type of endeavor. A CPFF meant that "contractors had no capital invested in the plants; they contributed no operating funds; they oftentimes utilized government free-issue materials; they had an assured market for their products; and they were reimbursed for all costs" (Kane 1995:37). It also assured them a profit for their time and energies.

During World War II most of the contracts between the Ordnance Department and the GOCO industrial facilities utilized the CPFF-type contract. There continued to be criticism of this type of contract as well as the military's reliance on large firms in military contracting. Most of the firms chosen to run GOCO facilities were from big business. Coca Cola, Proctor & Gamble, U.S. Rubber, Eastman Kodak, Goodyear, and Remington Arms operated GOCO facilities. Du Pont, and its spin-offs Hercules and Atlas, also ran 13 of the 23 GOCO P & E plants (Kane 1995:41).

This business was good for the companies and profits were high. In 1941, Du Pont cleared $77 million in profits and in 1942 it cleared $55 million in profits (Zilg 1974:357-358). In 1942, in the midst of federal investigations of sales violations by the companies, Du Pont, Hercules, and Atlas were convicted of a "joint price fixing scheme" (Derdak 1988:55). Du Pont alone paid a minor fine of $40,000 (Zilg 1974:358).

Technology

The GOCO Ordnance plant system during World War II consisted of 77 plants in 26 of the then 48 states in the nation. Nine basic kinds of facilities were included in the ordnance production program. These facilities consisted of load, assemble, and pack plants; propellant and explosive works; chemical works; small arms ammunition plants; case cup plants; gun tube plants; magnesium metal powder works; tank plants; and plants for the production of metal components for artillery ammunition. Radford was one of 23 P&E works.

The contractors who ran these plants for the government were called either "agent-operators" or Operating Contractors. The first wave of GOCO plants (those built before World War II) were run by companies with experience in manufacturing the desired products. During the second wave of construction, the limited number of private companies with prior experience in these manufacturing technologies forced the government instead to choose firms on the basis of their financial soundness and their experience with mass production and storage of goods. Many of the later LAP facilities were run by companies such as Procter & Gamble, Sherwin-Williams, and Quaker Oats (Walsh 1995:64-65).

The Mission of ROW

ROW's primary mission during World War II was the production of single- and double-base smokeless powder. In addition to making powder for rifles, machine guns, and conventional cannon, it also produced powders for trench mortars, chemical mortars, recoilless rifles, and large and small rockets (Anonymous 1955:21). Numerous raw materials used in the smokeless powder process were produced at Radford, including nitric acid, sulfuric acid, and nitrocellulose. ROW produced nitric acid from anhydrous ammonia and its oleum plant produced fuming sulfuric acid from raw sulphur (Anonymous 1957:12). Such explosives as nitroglycerine (for which the only other production unit was located at Sunflower), pentaerythritol tetranite (PETN), and pentolite were also produced at ROW. TNT was not produced at Radford until 1968. Although a TNT line was completed in June 1943, it was never used. Instead, Radford obtained its TNT from Virginia Ordnance Works in Glen Wilton, Virginia, until that plant closed in September 1942. ROW then obtained TNT from the Indiana Ordnance Works.

Pertinent Products

Smokeless Powder

Smokeless powder is actually neither smokeless, nor a powder, but a granulated substance which, when burned, is smokeless in comparison to the black powder used into the late nineteenth century. It is a slow burning explosive known as "propellant" and distinctive from "explosives," such as TNT, which are used as bursting charges (*RPW* 1941i:4). It was first produced by Vielle, a Frenchman in 1885 and developed further by Alfred Nobel of Sweden and Able and Dewar of Great Britain (Kane 1995:127). Smokeless powder manufacturing was codified by Ordnance officials in a 1940 procedure manual (MacDonald and Mack 1984:25). The powder produced at ROW was both single-base and double-base, according to the number of active ingredients. In single-base powder, used for cannon and small arms, nitrocellulose was the active propellant. In double-base powder, used for rocket propellant, nitrocellulose and nitroglycerine were both used.

Nitrocellulose: Nitrocellulose is the basic constituent used in the manufacture of smokeless powder (Anonymous n.d.c:Nitrocellulose Section, p.1). It is produced by treatment of cotton linters or wood pulp with a mixed acid (Anonymous n.d.c:Nitrocellulose Section, p.1). Cotton linters are short ($^1/_{16}$-inch) strands retrieved from the cotton seed on a second cutting. These linters are purified through a series of caustic washes and chlorination. At ROW, purified cotton linters were stored in a warehouse (Building 1000) then shredded and dried in an oven in Building 1010 to remove any excess moisture (Figure 4; Anonymous 1970:3). This production process, as well as the following, took place on the "A" line in various buildings dedicated to specific procedures.

Nitrating: Nitration of the linters was the first step performed at ROW (Building 1012; MacDonald and Mack 1984:25). Linters were "dipped" with mixed acid—a sulfuric and nitric acid blend (stored in Building 1005; Anonymous 1970:3). The cotton was sent to centrifugal wringers to extract excess acid, washed again and sent to the boiling tubs (Building 1019; MacDonald and Mack 1984:25). Unwanted chemical compounds were removed by boiling the cotton in acidulated water (MacDonald and Mack 1984:25). Transferred to the beater, or pulping, house (Building 1022; Figure 5), the cotton was ground to the desired consistency and put through a series of boilings and washing to remove impurities (Building 1024; Anonymous n.d.c:Purification Area Section, pp.15-20).

Production: The Dehydration House was the first step of the actual "powder line" (Building 1500; MacDonald and Mack 1984:25). A measured amount, or charge, of cotton was dumped onto a hydraulic press and formed into a block (MacDonald and Mack 1984:25). Alcohol, pumped through the block, removed any excess water and was, in turn, pressed out. A block breaker (Building 1560) then broke the nitrocellulose into smaller pieces, which were sent to the Mix House (Building 1508; MacDonald and Mack 1984:25). Here, ether and alcohol and other chemicals were added and mixed with the nitrocellulose and sent through macerators. The nitrocellulose was again pressed into blocks, forced through a wire mesh, blocked again and pressed through dies into string-like fibers (Building 1513; MacDonald and Mack 1984:26). These fibers were cut to the desired length, according to ballistics specifications.

Finishing: Solvent recovery was the next step in the process. Most of the ether and alcohol remaining in the powder was removed here by circulation of warm inert gas (Building 1622; Anonymous 1970:4). This process could take six to eight days (Anderson 1984:2). The rest of the solvent was removed in the Water Dry House (Building 1668) where the nitrocellulose was placed in a hot water bath (Anonymous 1970:4). The powder was then sent to the Air Dry House (Building 1725; Figure 6) where warm air was blown through the powder (MacDonald and Mack 1984:26). Glazing with graphite was required for rifle powders, but not cannon powders, and took place at this point (Building 1800; Figure 7) (MacDonald and Mack 1984:26). Screening took place to remove imperfect grains and foreign materials (Building 1850;

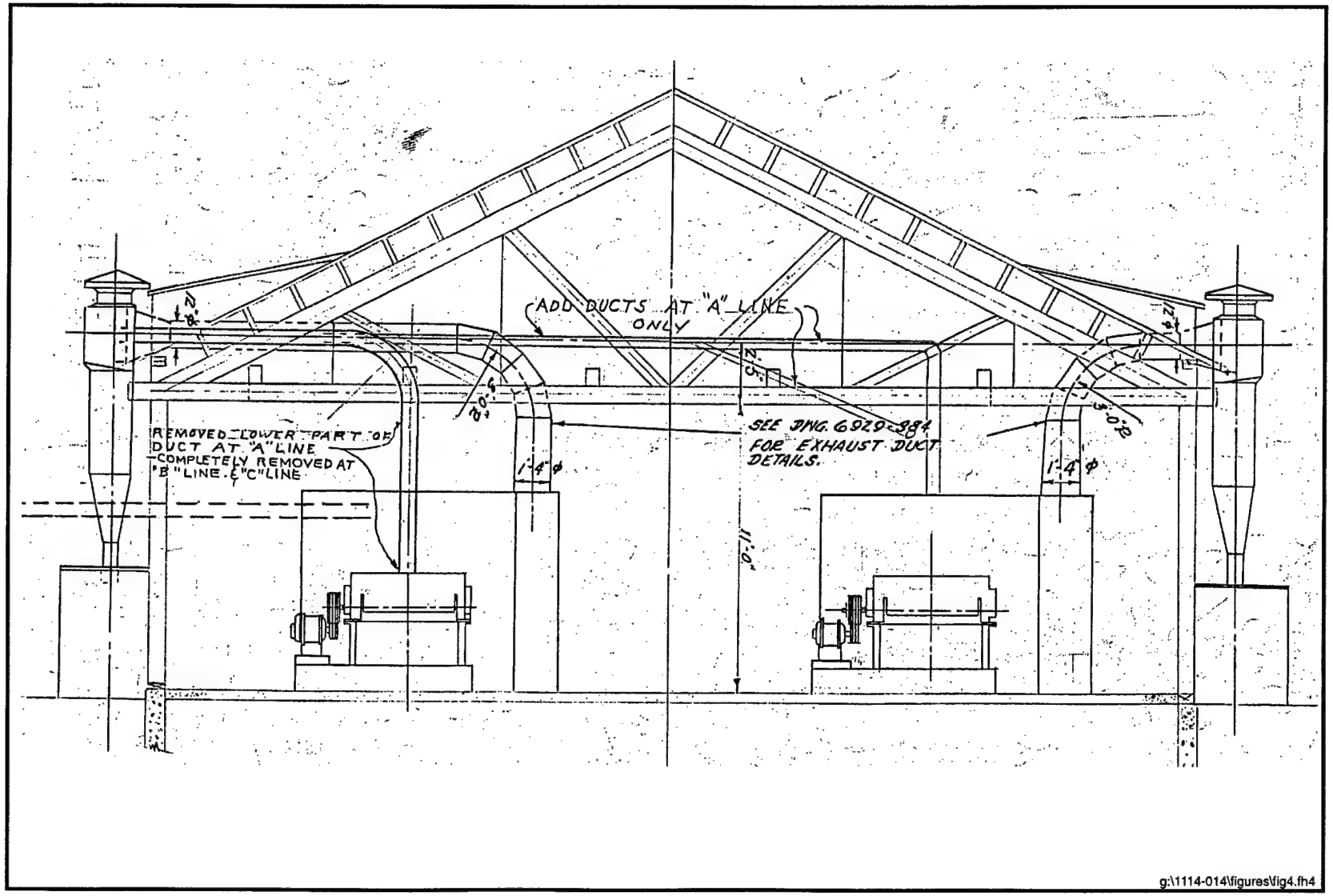


Figure 4. Interior elevation of Building 1010, Cotton Dry House, where cotton or wood pulp was dried and shredded (1940 HPC Drawing #6929-252).

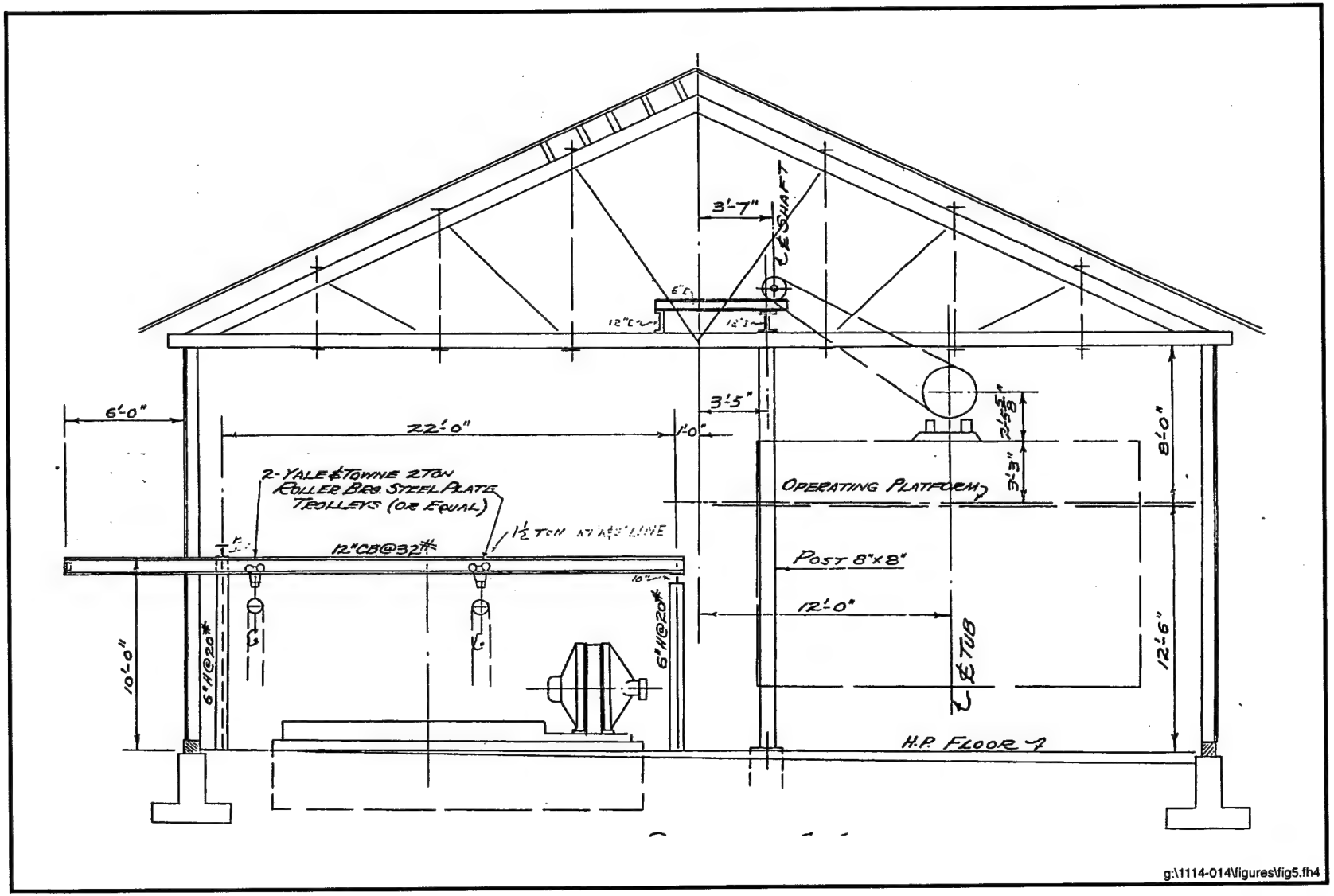


Figure 5. Interior elevation of Building 1022, the Beater House, where cotton was ground (1940 HPC Drawing #6929-257).

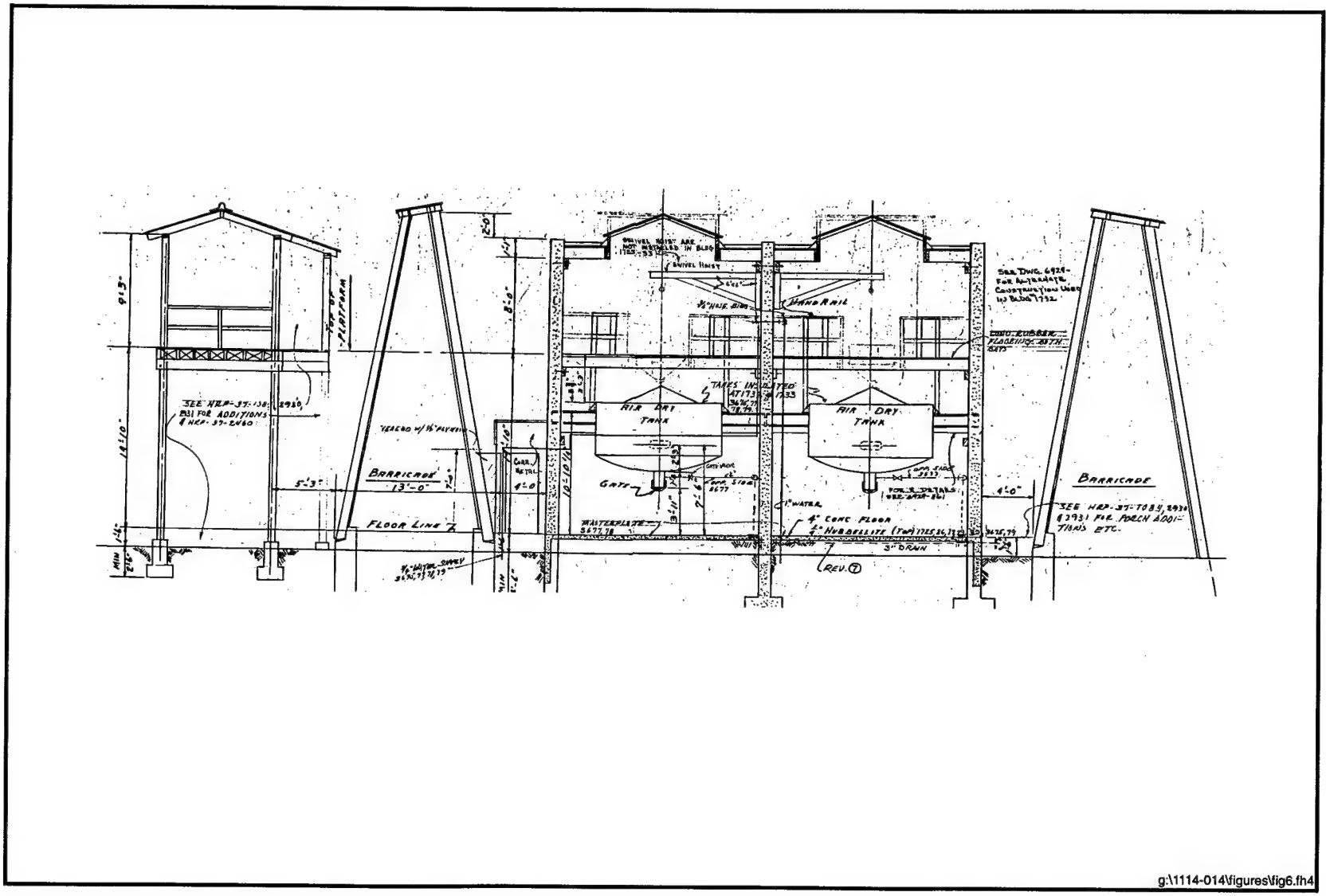


Figure 6. Interior elevation of Building 1725, the Open Tank Air Dry House, where solvent was removed using warm air (1940 HPC Drawing #6929-834).

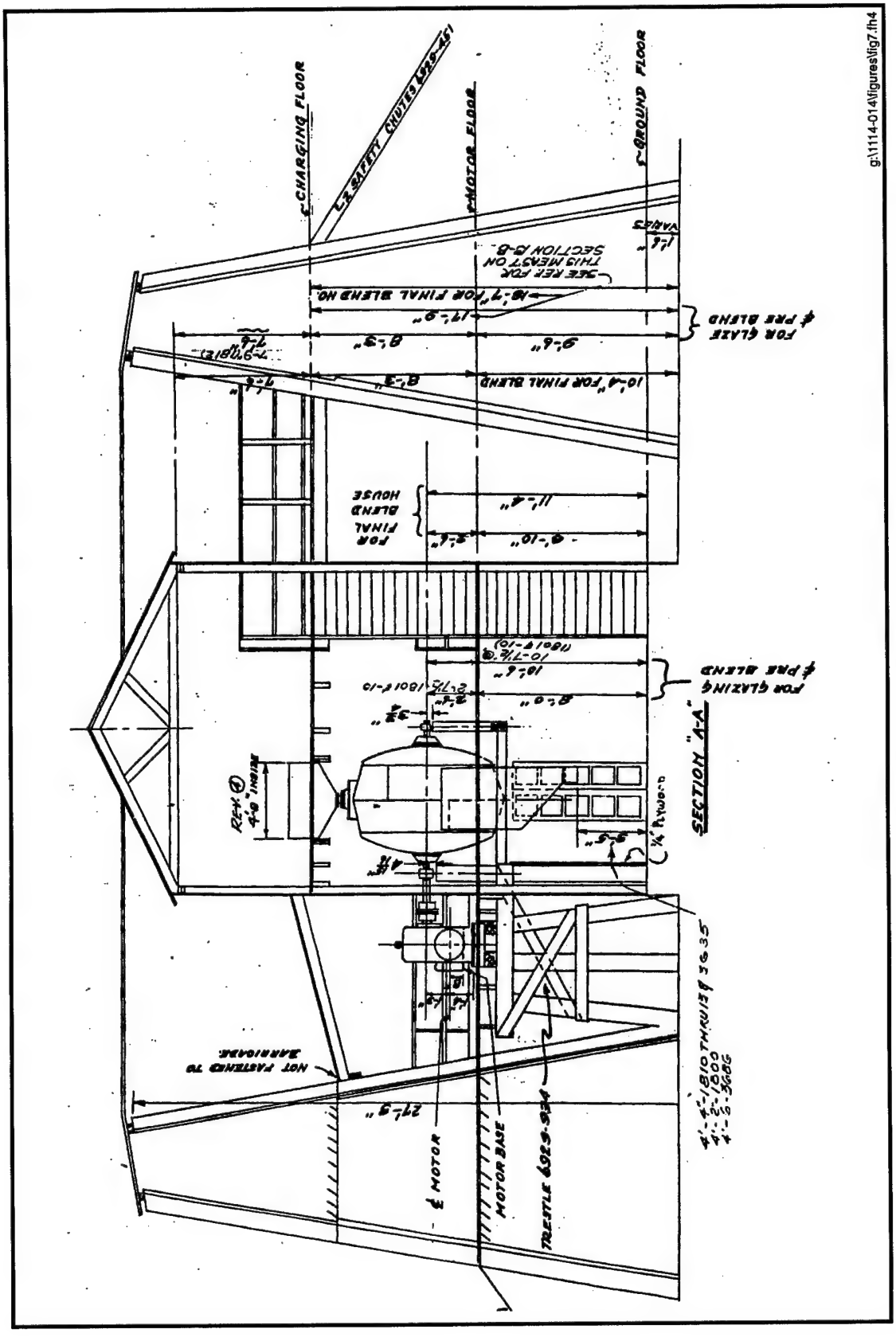


Figure 7. Interior elevation of Building 1800, the Glazing House, where rifle powder was glazed with graphite (1940 HPC Drawing #6929-632).

Anonymous 1970:5). Lastly, various batches of powder were triple blended (Building 1825) to obtain uniformity and then packed (Building 1875) (Anderson 1984:3). It was then either sent to the magazines for storage or to the powder loading platform (Building 1992) for shipment.

Beginning in 1941, the National Defense Research Committee, the California Institute of Technology, and Hercules Powder Company worked together to develop a solventless procedure whereby smokeless powder was produced by a dry-extrusion process. This made it easier to produce large grains of powder needed in rocket propellant. Radford's dry-extrusion line, approved in February 1942, was the first authorized in the United States (Buildings 5000-5016) (Kane 1995:132; MacDonald and Mack 1984:28).

From 1941-1945, Radford produced 472,546,440 pounds of nitrocellulose. The first run of powder at Radford, produced in April 1941, was made from nitrocotton shipped from Hercules' Parlin Plant. "A total of approximately 4,000,000 pounds of nitrocotton was sent in from Parlin prior to the start of acid and nitrocotton operations at Radford" (HPC [1945]a:1099). By the end of the war, the three smokeless powder lines at Radford had produced over half a million pounds of single- and double-base powder.

Pentolite

During World War II, ROW and Plum Brook Ordnance Works (Sandusky, Ohio) were the only GOCO plants to produce pentolite. It was used in bazooka ammunition, rocket projectiles, rifle grenades, anti-tank explosives, and for demolition purposes. Pentolite does not react with metal and can be heated below the boiling point of water and, in a paste-like form, can be poured into shells, which is faster than press loading (*RPW* 1944a:1).

Pentolite is a mixture of pentaerythritol tetranite (PETN) and trinitrotoluene (TNT) and is 20 percent more powerful than TNT alone. PETN, a component of pentolite, was invented in 1891. ROW was the only plant to produce PETN, and production began in late March 1942. The only use for PETN at ROW was in the production of pentolite. PETN was made by nitrating an alcohol, which in turn was made by treating a mixture of formaldehyde and acetaldehyde with lime (*RPW* 1944a:1). When PETN, which by itself was 40 percent more powerful than TNT and highly sensitive to friction, was combined with TNT, the mixture produced the high explosive pentolite, which was safer to handle.

The site chosen for the Pentolite Plant contained 51.8 acres and was located at the extreme east end of the plant property. The design of the plant was based on the Pentolite Plant at Hercules' Kenvil plant. Plant facilities consisted of 17 process buildings, six storage buildings, and five service buildings (HPC [1945]a:1310):

Process	Storage	Service
2 nitrating houses	1 P.E. warehouse	1 office
2 neutralizing houses	1 box storage	1 laboratory
2 pentolite houses	1 ingredient warehouse	1 change house
1 TNT opening house	1 TNT magazine	1 gate house
4 dry houses	2 rest houses	1 maintenance shop
4 box lining houses		
1 nailing house		
1 acetone recovery house		

The first charge of pentolite was processed on March 28, 1942, and completed on April 8 (HPC [1945]a:1332). Early production was limited due to continuation of construction and changes in equipment. With an expected plant output of 300,000 pounds/month, this rated capacity was exceeded in July 1942 when 455,520 pounds were manufactured (*RPW* 1945d:5). On November 26, 1944, eleven charges of PETN were

made and shipped to Picatinny Arsenal (HPC [1945]a:1357). After 41 months of production (through December 1944) ROW produced 27,661,445 pounds of pentolite (HPC [1945]a:1358).

Operations ceased at the Pentolite Plant on August 27, 1945. During the early 1950s a "clean up" took place at ROW. Nearly 100 buildings were demolished, including the entire Pentolite Plant and the unused TNT manufacturing area. It is assumed that all buildings and equipment used in PETN production were removed when the Pentolite Plant was removed in the 1950s. According to the best knowledge of current employees, no PETN buildings nor equipment survive at RAAP today (Terry Thompson, personal communication 1995). The site of the Pentolite Plant is now a testing area.

Trench Mortar Powder

Trench mortars were one of the Army's most powerful weapons used in Pacific warfare because of their strength and mobility. A "chemical mortar," which is approximately four inches in diameter, could propel the 26-pound projectile up to 4,000 yards (*RPW* 1944b:1). Trench mortar powder consists of a mixture of nitrocellulose and nitroglycerine and other chemicals. The mixture, or colloid, was then rolled out several times until it resembled an opaque sheet. The sheet was broken and rolled out again to the thinness "of writing paper." The rolled or strip powders, especially developed by Hercules as the main propellant in trench mortars, were cut into small pieces, one to two-and-one-half inches square. The squares were placed into piles about 12 inches wide and 41 inches long. These squares were then stitched together and cut into strips of the desired width. The production of trench mortar was a highly precise procedure. When rolled out, the thickness of the sheet of powder could not vary more than $^{1}/_{500}$ of an inch. Finished squares of powder could not vary more than $^{2}/_{1000}$ of an ounce in weight (*RPW* 1944b:1, 3).

RAAP, which retains the capability of producing trench mortar powder and does so from time to time as the need arises, is able to produce sizes ranging from 4.2 mm, to 60 mm, 81 mm, or 120 mm, but during the last year has only manufactured the 4.2-mm and 60-mm sizes. This process occurs in the Rolled Powder areas, both First Rolled Powder and Fourth Rolled Powder. First Rolled Powder area, however, may soon be shut down and all work moved to Fourth Rolled Powder (Terry Thompson, personal communication 1995).

Acid Department

In the original contract, the mission of the ROW acid department was to produce nitric acid, to concentrate weak nitric acid, to prepare mixed nitrating acid (a combination of nitric and sulfuric acids), and to operate the acid recovery and sulfuric acid concentrators (HPC [1945]a:878). Supplement #2 to the contract, however, called for the production of nitroglycerin at ROW and, thus, the acid department was responsible for the production of mixed acid for nitroglycerin. Supplement #5 to the contract called for ROW to produce TNT at the plant, adding oleum production to the responsibilities of the acid department. The acid department also supplied 98-percent nitric acid to the Pentolite Plant for manufacture of PETN and was responsible for recovery of spent acid from PETN manufacture as well (HPC [1945]a:878). According to Hercules ([1945a]:913) totals for production in the acid department from 1941-1945 were:

Product	Pounds Produced (1941-1945)
Sulfuric acid concentrate	1,678,117,863
Strong nitric acid	739,460,043
Weak nitric acid	607,342,529
Oleum	236,988,360
Nitroglycerine	17,846,057

The *Acid Manual of Standard Practice* was written by the ROW acid supervisory staff and sent to Volunteer, Badger, and Sunflower ordnance works (all Hercules operated). This manual described the oleum, nitric acid, and sulfuric acid operations in detail (HPC [1945]a:894).

Nitroglycerine (NG): "Nitroglycerine was discovered in 1847 by an Italian named Ascanio Sobrero. It is a high explosive made from a mixture of glycerol, nitric acid, and sulfuric acid" (Kane 1995:141). At ROW, NG was produced by the nitration of glycerine in a mixed sulfuric/nitric acid. Glycerine was purchased from Proctor & Gamble, Lever Brothers, and Colgate (HPC [1945]a:885). Glycerine was slowly added to the mixed acid and kept cool by coils filled with chilled brine (Building 3630). Spent acid was removed through a settling tank. The NG was washed and emulsified then moved to the Neutralizing House (Building 3637) where soda ash removed residual acid and final washing occurred (MacDonald and Mack 1984:27). The first charge of nitroglycerine was made on September 26, 1941; peak production was reached in December 1942 with 666,469 pounds produced (HPC [1945]a:900).

The original NG plant (NG 1) is still standing at RAAP. A blast demolished the nitrating building but the mix, screen, and buggy houses are all original and retain their original equipment. This old equipment is held in reserve and generally not used because the new nitrating building incorporated many of the processes formerly housed in these buildings (Terry Thompson, personal communication 1995).

During the Korean War build-up at Radford, a second nitroglycerin plant (NG 2) was constructed (MacDonald and Mack 1984:31). In January 1978, NG 2 exploded, demolishing most of the buildings in this complex (MacDonald and Mack 1984:32). Those buildings that were not destroyed were torn down and the complex completely rebuilt (Terry Thompson, personal communication 1995). During the period when NG 2 was out of commission, NG 1 was reactivated (MacDonald and Mack 1984:32).

Sulfuric Acid: Sulfuric acid is required in the production of nitroglycerine. Both weak sulfuric acid and strong, or concentrated, sulfuric acid were produced at ROW. Weak sulfuric acid was obtained by burning sulfur, which produced sulfur dioxide. The sulfur dioxide was then made into sulfur trioxide through contact with a platinum catalyst. The sulfur trioxide was mixed with water to produce weak sulfuric acid (Kane 1995:156). At ROW, strong sulfuric acid was produced by concentrating weak sulfuric acid through a Mantius Concentrator, which boiled the weak acid, thus dehydrating it (Kane 1995:156). Presently, much of the activity in this area concentrates on recovering and recycling sulfuric acid instead of producing it although it can be produced from the 20-percent oleum solution that is now purchased (see below) (Terry Thompson, personal communication 1995).

Nitric Acid: Nitric acid is used in production of nitrocellulose, nitroglycerine, TNT, and other nitrocompounds. The nitric acid facilities at ROW were of standard industrial design. Anhydrous ammonia was first purchased from a commercial supplier, then later supplied by Du Pont's Morgantown Ordnance Works in West Virginia and its Belle Plant (not a GOCO facility) at Belle West, Virginia, and by the Buckeye Ordnance Works in South Point, Ohio (HPC [1945]a:884). "Liquid ammonia was vaporized and mixed with heated compressed air in the presence of a platinum catalyst to form nitrogen oxides. The nitrogen compounds were then further oxidized with air and fed into an absorption tower, where they combined with water to form 60% nitric acid (Buildings 700-702)" (MacDonald and Mack 1984:27). To achieve the desired purity for use in nitrocellulose production, the 60-percent acid was concentrated by dehydration with strong sulfuric acid (Building 703). The spent sulfuric acid was brought back to strength for recycling in the nitric acid operation (MacDonald and Mack 1984:27).

Oleum: Oleum is a corrosive oil formed by the mixture of sodium trioxide and sulfuric acid and is referred to as "fuming sulfuric" (Kane 1995:155). Sulfur for oleum production was purchased from the Texas Gulf Sulfur Company (HPC [1945]a:885). The first sulfur was burned April 22, 1943 (HPC [1945]a:905). The oleum plant was shut down and placed in stand-by in 1986. Since that time a 20-percent oleum solution has been purchased for use in acid production (Terry Thompson, personal communication 1995).

Technological Advances

It is difficult to discern from the written histories of the plant the exact relationship between the research offices of Hercules at its Wilmington, Delaware, offices and those at Radford. It is clear that Hercules was responsible for several technological advances during the war and that several of these advancements were first implemented at ROW (*RPW* 1945f:5). "The plant was used as an experimental proving ground for various techniques [and in] other areas improvements were worked out to be put into practice later by the other [ordnance] plants" (*RPW* 1945f:5).

Rolled Powder

The development of rolled powder, as well as the processes and equipment used, was necessitated by the increased need for trench mortars in World War II. The Ordnance Department and Hercules officials worked together to provide for the manufacture of the increment explosive on a large scale. Special streamlined equipment was designed by Hercules, including sewing machines operated by remote control (*RPW* 1945d:4). (These remote control sewing machines, although they may have been modified, are still used at RAAP in the Rolled Powder areas [Terry Thompson, personal communication 1995]). "Hercules research improved the accuracy and uniformity of the load, greatly reduced the cost of manufacture and introduced unexpected advantages in safety of manufacture and use" (RPW 1944b:1).

The process for producing rolled powder begins with nitrocellulose, wet with water, which is then mixed with nitroglycerine and modifying agents. It is rolled and dried, then dried again into big sheets that are cut up into smaller pieces (*RPW* 1945d:4). The first rolled powder unit was put into operation on October 1, 1941, and full rated capacity was reached on January 15, 1942. In 1945 ROW embarked on construction of its fourth rolled powder unit, which was to consist of nine new buildings. This construction was stopped short of completion when the war ended in August.

Before the increment packaging of rolled powder was undertaken at Radford in June 1945, this work was performed at the New River Ordnance Plant. The process, similar to inserting medicine pills into cellophane, was predominantly done by women. In October 1944 it was reported that 52.7 percent of the work force in the Trench Mortar Powder Area were women (*RPW* 1944b:1).

Other Advances

Hercules had helped to develop the powerful, high explosive PETN that, when combined with TNT, formed pentolite. As noted above, pentolite was more stable than PETN and more powerful than TNT. In 1942, Hercules' engineers at Radford developed a process for manufacturing pentolite in a slurry that facilitated its loading into shells and bombs (Dyer and Sicilia 1990:235).

The supersonic method of testing rocket powder with high frequency sound waves was developed by Hercules engineers, in conjunction with Brush Development Company of Cleveland, Ohio, and was first undertaken at ROW. Prior to testing with sound waves, large x-ray pictures of each powder grain were taken to detect voids in the powder grains. These voids affected the functioning of the rocket, its the accuracy, and could result in misfiring at ignition. When the output of powder increased so dramatically in March 1944, it became apparent that there would not be enough x-ray film produced in the country to supply the demand at its peak (*RPW* 1945b:2). The development of the sound wave process was both a time-saving and cost-saving improvement. The high frequency sound wave was "generated by a crystal connected to a specially designed electronic circuit" (*RPW* 1945b:1). The sound wave was run through the grain and, if the grain contained a flaw, the sound wave created a deflection that registered on a meter (*RPW* 1945b:1). This method was more sensitive than the x-ray method and reduced operations costs.

Improvements in nitrocellulose manufacturing can be attributed to Hercules, as well. A method of substituting wood pulp in place of cotton was produced by a Hercules chemist in the 1930s and was an important alternative for the GOCO facilities. By mid-1941 there were not enough cotton linters to meet the needs of the nitrocellulose facilities. The use of wood pulp toward the end of the war allowed the facilities to maintain their high level of smokeless powder production (Kane 1995:136). Both cotton linters and wood pulp continue to be used in the manufacturing process at Radford today. For some processes cotton linters work better, while for others, wood pulp is more suitable. The 1940s-vintage equipment is still being used to prepare the wood pulp because, to date, equipment that works better has yet to be found (Terry Thompson, personal communication 1995).

State-of-the-Art Equipment and Processes

Whenever possible, GOCO facilities used state-of-the-art technology (Kane 1995:177). Because Hercules was one of the top producers of smokeless powder in the country, it is logical to assume that its facilities would have had the benefit of the latest knowledge in the field. Changes in equipment occurred throughout production to increase efficiency, safety, and production.

Radford was the only GOCO facility to have its own research and development department. The department conducted experimental work and was responsible for testing the strength of each lot of powder used for cannon , rocket, small arms, and closed bombs (*RPW* 1945e:2). Small arms ammunition and large caliber powder were tested using both chronograph and photoelectric screen methods. In the older chronograph method a shell was fired, breaking a metal wire at the end of the gun muzzle that started the chronograph recorder. When the bullet hit a metal plate downrange, the chronograph stopped and the fire power was established by calculating the distance of the shot and the time traveled (*RPW* 1945e:2). The cannon range was conducted in the same manner, but on a much larger scale. Trench mortars were tested by firing them through large loops of electric wires, which were connected to the chronograph.

Contribution to the War Effort

ROW reached its full rated capacity on September 22, 1941, just six months after start-up. On October 13, 1941, with all three smokeless powder lines in production, Radford's output exceeded the entire national output of smokeless powder at the start of World War II (Baldwin 1942:221). Production continued to increase, until the plant reached its highest production figure of 170 percent of full rated capacity (*RPW* 1945g:5).

In 1941, the first year of production, ROW produced 38.2 million pounds of powder (Dyer and Sicilia 1990:229). According to Hercules ([1945]:ix) the amounts of explosives packed per years of production were as follows:

Year	Pounds of Explosives Packed
1941	38,236,102
1942	147,225,995
1943	161,250,169
1944	142,957,455
1945	106,813,125

Between 1941 and 1945 ROW production efforts resulted in an average of 15.7 million pounds per month of propellants produced, with 10 pounds of production per hour worked (Anonymous 1970:4). In total ROW produced 596,482,846 pounds of munitions (Table 6).

Table 6
Total Propellant Production at ROW 1940-1945

Type of Propellant	Pounds produced
Cannon powder, single-base	430,124,960
Small arms powder, single-base	73,307,772
Cannon powder, double-base	32,990,789
Pentolite	27,661,415
Trench mortar powder, increments	11,494,504
Rocket powder, solvent	10,794,498
TNT (produced at VOW)	4,846,150
Rocket powder, solventless	2,857,188
Reclaimed and reblended powder	1,781,763
Experimental explosives	623,807
Total	596,482,846

Sources: Anonymous n.d.a.:4; Anonymous 1957:13; HPC Powder Company [1945a]:39
Note: TNT production was never undertaken at Radford during WW II. TNT was produced at Virginia Ordnance Works under the auspices of ROW starting in January 1942. Before acquisition of VOW and after its subsequent closing, ROW received TNT from Indiana OW.

NEW RIVER ORDNANCE PLANT

The New River Ordnance Plant was also part of the "first wave" of defense projects that included the Radford Ordnance Works. It served as a guide or demonstration bag loading installation for other facilities including the Hoosier Ordnance Plant in Charlestown, Indiana, and Coosa River Ordnance Plant in Talladega, Alabama (HPC [1945]b:98). During the same period the Ordnance Department was talking with Hercules Powder Company officials about designing and operating a smokeless powder plant, they also were discussing a companion bag loading facility. On September 11, 1940, the Ordnance Department sent a letter of intent to Hercules opening negotiations for "management services covering supervision, direction, and control of designing, engineering, constructing, and equipping a bag load plant . . . with an estimated production capacity of 225,000 pounds of powder per day on a cost-plus-fixed-fee basis" (HPC [1945]b:21). The plant was also to furnish consultant service for other similar plants. The contract was signed December 17, 1940 (Figure 8; HPC [1945]b:36).

The logical location for a plant whose purpose was to load the propellant powder charge into bags was to be in close proximity to the manufacturing plant. The original plan for ROW was to site the companion bag loading facility in the Horseshoe Bend area of the plant. Early publicity about the construction of the "new powder plant" confirms that the Horseshoe area was the first choice for the location of the bag loading facility (*Montgomery News Messenger* [*MNM*] 1940b:1) and as late as November 18, 1940, newspapers were reporting that the bag loading plant would be located there (*Roanoke Times* [*RT*] 1940). However, an explosion in September 1940 at Hercules' smokeless powder plant in Kenvil, New Jersey, changed site considerations and increased the amount of land needed for each facility. When it was determined that the manufacturing plant would need the land in the Horseshoe Bend, an alternate site for the bag loading plant was needed.

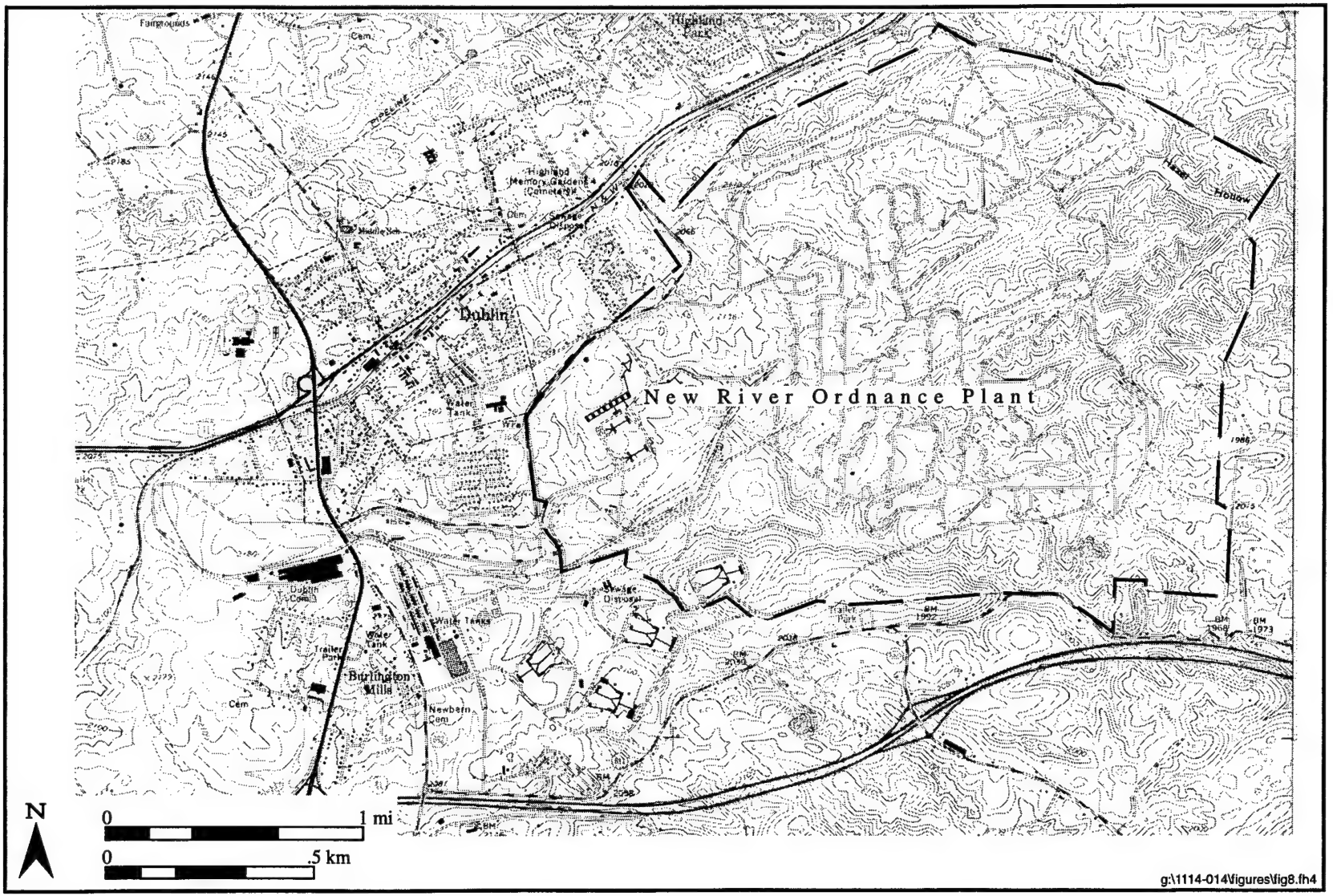


Figure 8. USGS Dublin, Virginia, map showing a more recent depiction of the layout of the New River Ordnance Plant.

There were several requirements for the new site. It required rail and highway transportation between the two plants, adequate water supply, and terrain that could accommodate the buildings with an allowance for safety distances but would permit expansion if necessary. It was estimated that at least 3,000 acres would be needed. In addition to the Ordnance Department and Hercules, the Norfolk & Western Railway Company was heavily involved in the site selection process—as it was at the ROW site (Baldwin 1942:8).

Initial interest focused on a 2,800-acre tract near Newbern in Pulaski County and purchase negotiations were begun in December 1940 (HPC [1945]b:27). At some point, it was determined that this site was too small for safety concerns and attention shifted to another nearby site. The alternate site was located south of Dublin and was near U.S. Route 11. The Norfolk & Western lines ran north of the site parallel with, and south of, Route 11 and a spur could connect the plant with the main line. This tract consisted of 3,834 acres with a hilly and rolling topography that was excellent for explosive safety, but more difficult for large building groups, railways, and roads (HPC [1945]b:28). It was farmland used primarily to grow wheat and graze cattle, with apple or pear orchards on most farms.

When negotiations began for the first, smaller tract of land, local agents acting under a local committee were used. Several problems with this approach surfaced; namely the length of time required, inequities and controversies in appraisals, and the failure to acquire property releases. On the second site, the Land Acquisition Division of the U.S. Department of Agriculture assumed the responsibility for acquisition. There were 45 separate tracts of land for the site, 24 of which were acquired by condemnation. Acquisition began on November 4, 1940 (HPC [1945]b:41, 42).

New River Ordnance Plant Layout and Design

When the government requested Hercules to design and operate the bag loading plant, only three such operations already existed: the Army plants at Picatinny Arsenal, New Jersey, and Curtis Bay Ordnance Depot, Maryland; and the Navy plant at Iona Island, New York. Hercules studied these operations and its Engineering Department, in collaboration with the Operating Division of its Explosives Department, prepared a preliminary layout and an estimate of the cost for one year of operation at NROP (HPC [1945]b:34).

The original Hercules plan called for five propellant-charge bag loading lines and three igniter-charge bag loading lines. A line consisted of two identical sets of buildings, set right and left, with a common service and administrative building. Each line was to be capable of loading any type of charge except stacked charges, from which one line was to be equipped to load. A facility to manufacture charge and igniter bags was also required. Storage for a 30-day supply of incoming materials and for a 60-day supply of finished materials was also included. These estimates required (HPC [1945]b:35):

20 warehouses for inert (non-explosive) materials
3 black powder magazines
20 smokeless powder magazines
50 propelling charge magazines

In the final contract for NROP the number of bag loading lines decreased by one each, resulting in four propellant charge bag lines and two igniter charge bag lines. The final number of magazines included 87 for smokeless powder, two for black powder, and 59 for high explosives (MacDonald and Mack 1984:23), as well as 13 inert warehouses (HPC [1945]b:72). Table 7 provides a breakdown of construction units at NROP.

Table 7
Construction Units at the New River Ordnance Plant

Area	Process	Storage	Service	Total
Office & Administration Area			25	25
Staff houses			15	15
Shops and Stores		31	13	44
Power and Water			13	13
Bag Manufacturing	1			1
Bag Loading	8	24	11	43
Igniter Area	4	6	6	16
Black Powder	3	1	5	9
Magazine Area		89	12	101
2 Black powder igloos				
87 Smokeless powder igloos				
Flash reducers	8	4	1	13
Black powder	3	3	2	8
Total	27	158	103	288
Miscellaneous:				
26 Sentry towers				
59 Igloos (constructed by ROW)				
78 Hose Houses				
20 Sprinkler Valve Houses				

Source: HPC [1945b]:112

Bag Manufacturing Buildings

A struggle ensued between design recommendations made by Hercules and the ideas of the Ordnance Department in several areas including bag manufacturing buildings, bag loading lines, and storage magazines. The Ordnance Department leaned heavily toward the existing design of its Picatinny Arsenal facility. However, Picatinny had evolved over a number of years and the arrangement was not the most logical or efficient. Although Ordnance wanted two separate buildings for bag manufacturing, Hercules prevailed with one building. Half of the building contained the sewing machines and the other half was composed of facilities for printing, punching, and cutting operations.

The more efficient layout cut costs and personnel and increased productivity. The original quota for bag production at NROP was 20 percent over that of Picatinny. Hercules usually averaged five to ten percent above the quota and the most experienced operators averaged 100 percent above it (HPC [1945]b:83).

Bag Loading Lines

Hercules designed all the equipment for the bag loading plants with the exception of equipment for loading stacked charges. The Hoosier Ordnance Plant developed the stacked-charge machine that was finally used at NROP. Hercules had wanted to use two-way loading in individual operation rooms. Although Ordnance denied this in 1941 for NROP, it was put into operation at the Hoosier Ordnance Plant and later became standard practice (HPC [1945]b:319).

Magazines

The Ordnance Department wanted an igloo design with a semi-cylindrical shape of reinforced concrete covered with earth. It believed that in case of an explosion, the front end would blow out in a straight line, while the rest of the igloo remained intact. Hercules preferred its standard type of light, shatterable construction.

The Ordnance Department insisted on its design and furnished its own plans with a door designed by Hercules. Later experience, however, proved the theory wrong. During a TNT explosion, the entire igloo was disrupted and large portions flew great distances. During construction, Mason & Hanger requested and received authorization to change the plan to a more practical design and Hercules tried to have the floor level raised to truck-bed height. Although this request was denied at NROP, it was later used at other plants (HPC [1945]b:86).

Other Buildings at NROP

Administration Building

The Administration Building housed the executive staffs of the War Department and Hercules. There were a number of designs including a complete set that was first approved and then rejected because the type was too permanent. The final plan duplicated the Mason & Hanger Administration Building with the exception of a concrete vault for records (HPC [1945]b:82). It was not explicitly stated in the Hercules history if this referred to the Administration Building at ROW.

Warehouses for Inert Materials

The design of these warehouses was governed by the requirements of storage. Each warehouse was 48 feet wide by 208 feet long. As shortages of steel developed, the roof truss design switched from steel to wood. Those built at NROP had wooden frames and roof trusses, as did the smaller buildings. Steel continued to be used for the trusses of the large bag manufacturing building. Hercules' designs for these warehouses were used in other ordnance plants (HPC [1945]b:85).

Water Supply and Power House

Hercules' initial recommendation for a water source was Claytor Lake which was located about one and one-third miles from the plant's southern border. Claytor Lake was created in 1939 when Appalachian Power Company dammed the New River. Hercules felt that water should be pumped from the lake to the site. However, the Ordnance Department believed that the natural springs on the site would provide sufficient water. Unlike the ROW, water was needed only for drinking, sanitation, steam, and laundry purposes. Only

after flow tests were performed and several wells were dug, did the Ordnance Department approve Hercules' original plan and a pumping station of Hercules' design was built at the lake (HPC [1945]b:88). No power house was built at NROP because the electrical demand did not warrant one. Power was purchased from Appalachian Power Company.

Roads

Two systems of roads were insisted upon by Ordnance: one for personnel and one for transportation of powder. Each shift, 550 people had to be moved into the Bag Loading, Igloo, and Black Powder areas. Fourteen buses were purchased from the recently defunct World's Fair in New York for this purpose. It was also intended that the perimeter road be patrolled by motorcycles with sidecars. These roads were only constructed in nine-foot widths because all patrol traffic was to move in one direction (HPC [1945]b:92).

Ordnance Department restrictions on roads in the Magazine Area were difficult to follow given the terrain at this site. The specifications stipulated that the road must neither be a dead-end nor allowed to loop around the building but must have a separate exit that did not pass the building. They also required a level, 50-foot stretch in front of each building for loading or unloading. While the early magazines followed this dictum, later ones did not (HPC [1945]b:93). During the initial construction phase, 62.09 miles of roads were built for the NROP. The maximum road grade permissible was six percent although the actual grade was 5.27 percent (HPC [1945]b:93).

Staff Housing

Hercules prepared complete design plans for staff housing adopted from the Radford plant. However, the Quartermaster Corps rejected the plans in favor of others prepared by an architect-consultant. (The name of the architect-consultant was not available.) The number of houses to be built was reduced to 15 (HPC [1945]b:94, 96).

Hospital, Cafeteria, and Recreation Facilities

After some initial indecision and delay on the part of the government, Hercules was allowed to build a hospital based on its plans. The building was situated north of the administrative buildings and was equipped with a surgery and dispensary, eight beds, and room for 20 emergency cots in the basement.

Although a 300-person cafeteria was built, as well as the several canteens that were located in other areas, all recreation facilities were deleted from the plans before the contract was signed. After the major construction phase ended, the Mason & Hanger employment building was remodeled and used as a recreation hall under the supervision of an employees' association. The association provided billiard and table tennis equipment and the government later installed four bowling alleys. A baseball diamond, softball diamond, and tennis courts were also built.

Construction

Construction of the New River plant was undertaken by Mason & Hanger of New York, the contractor for the ROW plant, under a separate contract with the government that was signed on December 17, 1940 (HPC [1945]b:39). That this project was on a "fast track" is evident in the wording of the contract, which specified that the contractor should

in the shortest time possible, furnish the labor, materials, tools, machinery, equipment, facilities, supplies not furnished by the Government and services; and do all things necessary for the construction of [the] plant (HPC [1945]b:39).

Construction of NROP began on February 10, 1941 (Plate 3; HPC [1945]b:59). Mason & Hanger was just completing the construction of the nearby ROW smokeless powder plant which took priority over the NROP. Although the firm was instructed not to rob labor from the larger project for the New River job, there apparently were no problems in securing sufficient workers. The greatest number of workers at one time was 7,000 (HPC [1945]b:104). By the first of January 1942 the plant was virtually complete and the loading lines were in operation (HPC [1945]b:102).

Following suspension of bag loading operations in 1943, NROP was reactivated in 1944. This necessitated rehabilitation of the existing lines as well as new construction. New buildings for Bag Loading Line 5 were built as well as flash reducer loading buildings. A total of 209 drawings was used for the plant additions that were built between September 1, 1944, and August 13, 1945 (Table 8; HPC [1945]b:63).

Assistance To Other Loading Plants

The government contract with Hercules stipulated that NROP would furnish consultant services for other similar plants (HPC [1945]b:21). On December 31, 1940, only two weeks after the contract for NROP was signed, Brigader General L. H. Campbell, Jr., of the Ordnance Department requested that plans for NROP be sent to Shreve, Anderson & Walker who had just received the contract covering the design and engineering management for the construction of the Hoosier Ordnance Plant. Hercules also furnished plans to Wiedman and Singleton of Atlanta who had the design and engineering contract for a bag loading plant near Birmingham, Alabama. (This was the Coosa River Ordnance Plant near Talladega, Alabama. Brecon Loading Company, a subsidiary of Coca Cola Company, was the contractor-operator of Coosa River) (HPC [1945]b:98).

These firms were also invited to send their representatives to Hercules' main office where any information requested could be provided. Site visits to the NROP under construction were also arranged. Hercules furnished plans, specifications, and details of training, personnel, and organization to both of these firms and bag loading plants. Ralph F. Shreve of Shreve, Anderson & Walker wrote to Lieutenant Colonel J. G. Homes of the Ordnance Department in April 1941 expressing gratitude for the assistance and information furnished by Hercules and the NROP that facilitated the construction of the Hoosier Ordnance Plant (HPC [1945]b:99).

Operations

The operation of the NROP proceeded in fits and starts. Its production record was alluded to in a letter General Lewis H. Campbell, Chief of Ordnance, wrote to C. A. Higgins, president of Hercules Powder Company, on June 5, 1943. Although he complimented the plant on its part in the ordnance program he noted that,

> [t]he plant's career has been a checkered one, and the vicissitudes which have accompanied its operation have precluded the establishment of any long-time record of production performance which is comparable to that of the other two plants which have been engaged in similar work. Those who were charged with its operation will remember, however, that in the troubled and uncertain months before Pearl Harbor, and throughout the early period of the war, the plant acted as a mentor and guide to others in the industry and when the later load became too heavy, it was again able to carry its share (HPC [1945]b:325).

Plate 3. New River Ordnance Plant with construction underway, May 15, 1941.

Table 8
Rehabilitation and New Construction Costs at New River Ordnance Plant in 1944-1945

Building Number	Area	Total Cost
200	Service Area	153,872
300	Administration Area	93,297
400	Bag Loading Line No. 1	50,611
400	Bag Loading Line No. 2	70,899
400	Bag Loading Line No. 3	68,072
400	Bag Loading Line No. 4	48,174
500	Igniter Lines	7,944
500	Black Powder Area	5,980
700	Miscellaneous Utility Buildings	374
900	Magazine Area	9,749
8100	Flash Reducer Area	493,135
8120	New Black Powder Area	54,968
8500	New Bag Loading Line No. 5	117,116
	Land Improvements	324,227
	Leasehold Improvements	145,084
Grand Total		1,643,502

Source: War Department Industrial Facilities Report New River Ordnance Plant [9/1945]:1-5

Bag loading operations at the NROP began in the fall of 1941. NROP had four identical lines (400 series buildings) for loading smokeless powder and two identical lines (Buildings 500-527) for loading black powder igniter charges. Facilities for drying the powder prior to loading into bags were included with the black powder lines. Smokeless powder and black powder loading both conformed to the same basic loading procedure, the major operations of which involve cutting and sewing the bags and loading powder into them (MacDonald and Mack 1984:29). The size, shape, and powder load size were determined by the type of charge that was to be loaded. The cloth was cut to the specific size, printed with identification of the charge, and sent to the sewing room to be made into bags (MacDonald and Mack 1984:29).

"The bag loading lines are made up of buildings for the actual loading of the gunpowder and a number of widely spaced and barricaded storage magazines" (MacDonald and Mack 1984:29). The bag loading buildings were divided by thick concrete walls into small rooms where a limited number of operators weighed out the powder and loaded it into the prepared bags. The opening left in the bag for loading purposes was then sewn shut and the charge was inspected (MacDonald and Mack 1984:29). Certain types of ammunition required that several bags be tied together, thus forming a charge made up of several increments (MacDonald and Mack 1984:29).

With the war going well for the Allies in 1943, the United States was using less materiel than they had anticipated. During the fall of that year the War Department ordered cutbacks at or closure of several facilities. It had already been decided in the spring of 1943 to close New River and use it for storage only. Production ceased on May 24, 1943, affecting some 1,500 employees. Some of the employees were transferred to the ROW or other Hercules plants while others were laid off (HPC [1945]b:164). During this

period, powder produced at Radford was shipped to Indiana for loading at a larger bag loading facility (John Horvath, interview 1995).

Barely five months later, it was decided to begin rolled powder operations, which consisted of increment packaging at New River. The plant was converted for waterproofing trench mortar increments, a process described as "almost identical with that used to insert medicine pills into cellophane strips" (MacDonald and Mack 1984:30). These operations began during the early part of November 1943 and provided jobs for about 600 people (HPC [1945]b:166).

In another about-face, the NROP was reactivated in August 1944 for bag loading. When production schedules were increased in 1944, the Hoosier and Coosa River plants could not handle the increase. By this time much of the bag loading equipment at New River had been shipped away as excess and parts of the plant converted to other uses. Fortunately it was possible to locate and return much of its equipment as well as reinstate the personnel who had worked at NROP earlier in the war (HPC [1945]a:763). Bag Loading Lines 1 through 4 were rehabilitated and construction was begun on a fifth bag loading line. The production schedule was larger than it had ever been under its original contract. Table 9 provides a listing of the pounds of powder received by and shipped from the New River Ordnance Plant. Personnel requirements were predicted to be between 5,000 to 6,000 over the previous high of 3,600 (HPC [1945]a:763).

Table 9
Pounds of Powder Processed at the New River Ordnance Plant

Date	Lbs. of Powder Received	Lbs. of Powder Shipped
1941	13,201,012	2,744,804
1942	67,675,793	49,502,644
1943	92,946,682	86,731,211
1944	104,290,051	83,101,229
1945	49,453,330	65,881,465
Total No. of lbs.	327,566,868	287,961,353

Source: HPC [1945b]:iv

Training

Recruitment for personnel at NROP began while the Personnel and Training Department was also recruiting for ROW. It was felt that a bag loading facility did not require employees that were as highly technically qualified as those at Radford. Fewer supervisors were needed at NROP and the supervisors were selected based on their previous supervisory experience at manufacturing plants, regardless of the item made. For training, the supervisors were sent to Picatinny Arsenal where they trained in bag loading before the New River plant began production.

Hercules gave primary consideration to applicants who were stable workers and could perform selected tasks carefully. Proper training of unexperienced workers, however, was given important consideration as there was no ready supply of labor experienced in the ammunition industry. Several weeks of training were recommended followed by in-service training (HPC [1945]b:144). It had been decided that NROP would

not disrupt local industries by pirating their employees, so workers were recruited from outside the immediate area. At one point, however, approximately 60 percent of all applicants were residents of the Roanoke area (HPC [1945]b:152. Much of the new abor pool was recruited from the construction force that had been employed in the construction phase of the Radford plant. Clerical employees and all of the actual operators were hired at the onsite employment office at the plant site.

New River Ordnance Plant Today

The production output at NROP was uneven due largely to circumstances beyond its control, such as, first the closure and then the later start-up of the bag loading lines during the war. NROP was again closed and classified as surplus at the end of the war; however, in 1946 the Magazine Area (propellant storage) was withdrawn from surplus and placed in stand-by status (MacDonald and Mack 1984:31). Parts of the plant were later sold to local industry including the area where most of the buildings were located. Almost all the buildings and all equipment that remained on government property, with the exception of the magazines, have been dismantled. Only two buildings survive: a guard house and a search house still stand at the main gate today.

VIRGINIA ORDNANCE WORKS

The Virginia Ordnance Works (VOW), a contractor-operated plant involved in TNT production in Glen Wilton, Virginia, functioned as a subdivision of the Radford facility. The plant operated under an officer who was under the direct supervision of the commanding officer of the Radford plant (Voight 1945:307). The original TNT plant was founded by Triton Chemical Company of Wilmington, Delaware, (who also operated a TNT facility in New Jersey [Hudson 1993:A1]) and was later known as the Connolly Plant.

Triton began purchasing land in Glen Wilton in the fall of 1940. The company signed a contract with the Army and Navy to supply TNT and began production at the plant in June 1941 (Hudson 1993:A1). After the bombing of Pearl Harbor, the government made plans to expand its GOCO plants, including new construction of additional facilities. "The highest priority [among products] was for the manufacture of more TNT . . ." (Kane 1995:50). The Glen Wilton plant was seized by the government on January 15, 1942, "for the purpose of having it operated by Hercules Powder Company for the production of explosives" (HPC [1945]a:1362). Low production rates and a concern for safety may have served as additional reasons for the government action. Nonetheless, the plant was in operation for only a short period. By fall 1942, a new TNT production unit was being constructed at Radford and the equipment, materiel, and supplies at VOW were transferred to the Radford unit and VOW was closed on September 21, 1942 (Voight 1945:307).

Due to limited reference resources, little is known of the history of the TNT plant before government seizure. Local newspaper accounts and references within government documents provide the bulk of currently available knowledge of the Virginia Ordnance Works.

Site Selection/Installation

Located on the James River, Glen Wilton is a small community in the northern end of Botetourt County approximately 50 miles from Radford (Figure 9). From the mid- to late 1800s into the early part of this century, Botetourt's iron ore furnaces provided much of the employment for this area, the largest being Callie Furnace. The iron industry slowed in the 1920s, but in 1941 Triton Chemical chose the small village as the site for its second TNT plant. The site of this plant was a "natural cup" surrounded by mountains and was predominantly forest. The complex that housed Triton's Princess Furnace was located on land that

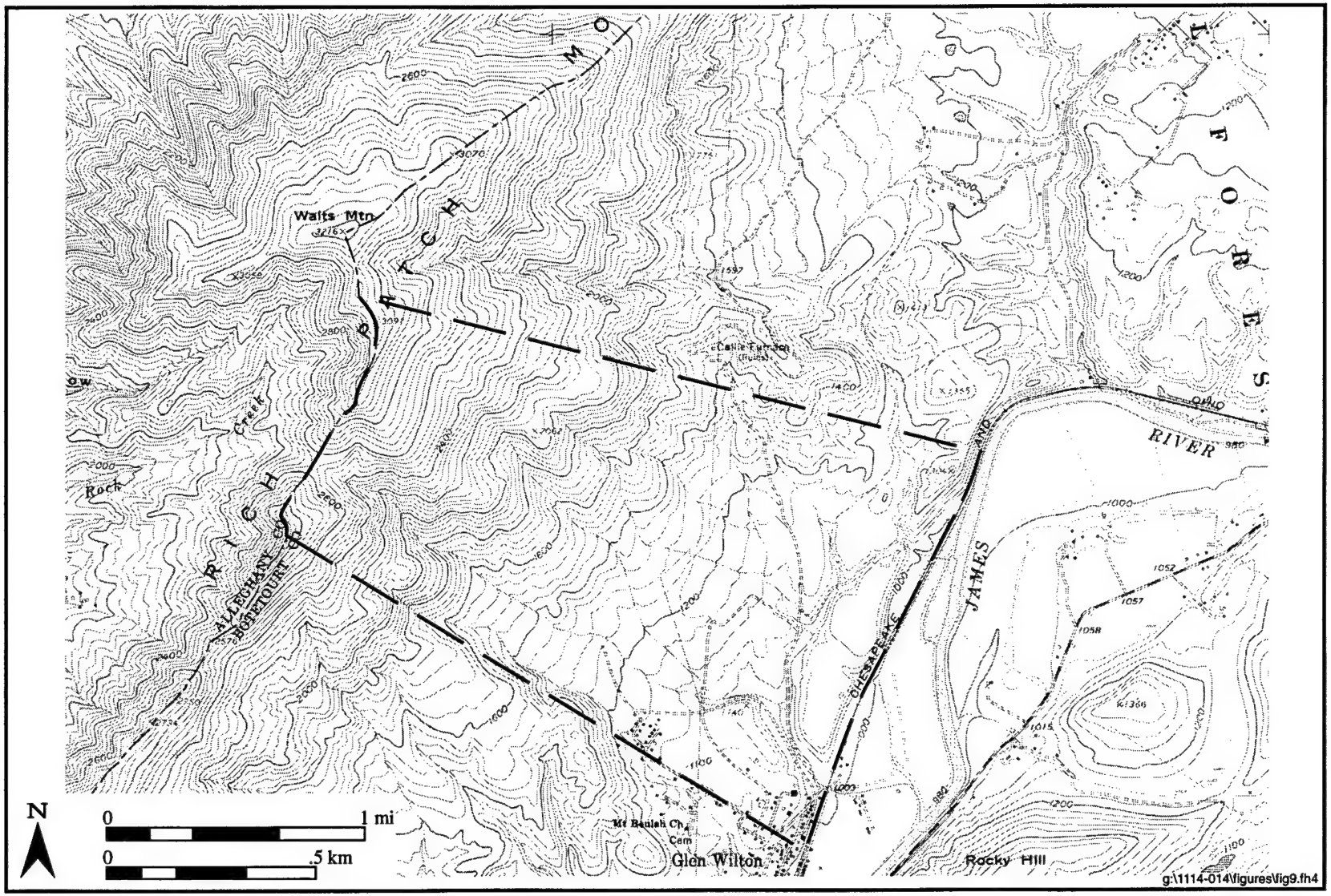


Figure 9. USGS Clifton Forge, Virginia, map showing a more recent depiction of the landscape where the Virginia Ordnance Works was located.

Triton acquired and it is believed that mining tunnels were used for TNT storage. For weeks rumors floated around that Du Pont was locating an explosives factory in Glen Wilton. County officials were tight-lipped throughout their dealings with the company. Finally, a deal was struck with the county's School Board and Triton bought the only school building for $5 to use as its headquarters (*Fincastle Herald [FH]* 1941e:1). This meant that Glen Wilton children would have to be bussed to Eagle Rock for school. The decision, made in secret, was not popular, but county officials were lured by the promise of 400 new jobs.

Triton eventually purchased over 1,800 acres for the plant, although production would take up only about 20 acres. Four houses on property owned by the Glen Wilton Corporation, and sold to Triton, were to be moved off by March 1, 1941 (Botetourt County Courthouse, Fincastle, Virginia [BCC] 1940:Deed Book [*DB*] 90:572).

Construction on the site began in late January 1941. By February, 125 construction workers were employed and a third shift had been added to the schedule (*FH* 1941a:1). By this time Triton had also contracted with the Chesapeake & Ohio Railway Company to build a spur track into the plant (*FH* 1941a:1). By March, eight or 10 buildings were in place and dedication ceremonies took place on June 25, 1941, with Governor Price in attendance (*FH* 1941b:1; *FH* 1941c:1). At the dedication, Triton President, M. J. Connolly, promised that the plant would be the world's largest producer of TNT.

By September 1941, however, Triton employed only 200 people. This was cause for concern on the part of Triton since part of the original contract with the county stated that if the company had not hired 400 workers by September 1941, the property would then revert back to the county on December 1 (*FH* 1940:1; *FH* 1941e:1). A "long drawn out controversy" ensued, with the citizens taking to court the case for the return of their school building (*FH* 1941f:1). County supervisors, school board officials, and Triton officials were pitted against the residents. Settlement was reached when Triton agreed to pay $6,000 for a new school building in Glen Wilton with the county furnishing an additional $2,500 (*FH* 1941f:1). Thus, Triton retained control of the TNT plant property.

Triton spent $1.5 million on the site, erecting 20 buildings on 1,831 acres, of which only 28 acres were occupied by operations. In 1942, when the government seized the plant, existing structures within the fenced operating area included a Weigh House, Mono House, two Bi and Tri Houses, Scale House, Fortifier House, Wash House, Grainer House, Screen House, Filter House, Half-Way House, Screen Pack House, Box Storage House, Compressor House, Toluol Shed, field office, field shed, two guard houses, and a Blacksmith Shop. Although the Power House, Laboratory, schoolhouse, and nine dwellings were also on the property, they were outside the fenced-in area (HPC [1945]a:1362). With construction of the plant, the town grew, as well. New stores, restaurants and a movie theater opened.

Takeover

By July 1941, Triton reported that each week 50 tons of TNT were being produced on three shifts. With the increased need for TNT, the U.S. government seized the plant on January 15, 1942, and turned over its operation to Hercules. The primary concern upon takeover was the safety of the plant and the workers. Triton did not have an established Safety Department at its Glen Wilton plant. Instead, this function was performed by the TNT superintendent. One fire in October 1941 had caused $3,000 worth of damage to the plant (*FH* 1941g:1). Pollution control was also a concern at the Glen Wilton plant. Large fish kills had been reported in the plant's vicinity early in the production phase (*FH* 1941d:1).

In an ironic twist, Triton fought the governmental takeover, much as the residents of Glen Wilton had fought Triton's takeover of its schoolhouse. A lengthy chancery suit followed, with resolution on June 14, 1943, when the district court decided "that the United States is entitled to acquire property and interest in the

property by eminent domain for military purposes" (BCC 1943:*DB* 93:69). Triton was paid $465,000 as "just compensation" for its land and buildings (BCC 1943:*DB* 93:69).

Organization

The personnel organization of VOW was similar to that set up at ROW. Since this plant was to operate as a branch of ROW, A. Van Beek, manager of the Radford plant, became manager of VOW and Colonel L. D. Booth of Radford was the commanding officer of VOW's War Department. J. E. Rothrock was appointed superintendent for direct supervision of the plant.

At the time the government seized operation of VOW, there were 162 Triton employees including 26 guards. "All employees who wished to remain with Hercules Powder Company were given credit for service worked with the Triton Chemical Company" (HPC [1945]a:1364). Several of Triton's supervisors were kept in their positions while other departmental positions were filled with personnel transferred from Radford.

Operations

The War Department planned to have the facility operate as a branch of ROW. Originally named ROW 2, the name was changed to Virginia Ordnance Works on January 26, 1942, however, and remained so. At the time of takeover, there was one TNT line in operation at the plant capable of producing 20,000 pounds of TNT per 24-hour period. A supplement to Radford's contract requested changes to facilitate an increase to 60,000 pounds per 24-hour period (HPC [1945]a:30). Arrangements were made to purchase equipment to put another line into operation, but on April 8, 1942, the Chief of Ordnance directed the discontinuance of all construction work at VOW (HPC [1945]a:31). No information was available in the plant histories as to why this decision was made.

Production under Hercules began on January 26, 1942. Prior to that date, employees were retained to clean up the facility. Because of this shortened production time, powder production in January 1942 was only 82,575 pounds. Over the subsequent months, however, production increased (HPC [1945]a:1365):

Month (1942)	TNT produced (lbs)
February	543,150
March	767,700
April	851,050
May	910,100
June	1,121,360
July (through the 20th)	653,965

Full capacity was never realized at the plant due to the lack of water and repair difficulties with the equipment. As early as October 1941 water shortages were threatening production (*FH* 1941g:1). A dam was built by the Triton Company north of the plant area that served both the town and plant. During dry spells there was not sufficient water for production. Water tanks were also put into use by digging three wells "which had a capacity of 150, 100, and 70 gallons, respectively, per minute" (HPC [1945]a:1366). Later a system was developed to re-use water by running it through an "earthen reservoir" and back into the system for general use. Another difficulty encountered was the insufficient storage space for incoming acid used by the plant to maintain its operations. This problem required constant scheduling and receipt of smaller deliveries of acid to the plant. The scheduling, ordering, and routing of the acid, including removal of spent acid, was the responsibility of the accounting department and transportation department.

During April 1942, production was slowed when the plant was shut down several times because of repairs and water supply problems. Constant repairs to the machinery at the plant were a continuing source of delay in production schedules and there were still difficulties in maintaining an adequate supply of water for cooling purposes. A log of these April delays shows production was delayed seven and one-half hours for repairs to the fortifier, 11 hours due to the lack of water, seven hours for repairs to the graining kettle, and eight hours for general repairs. Problems in the acid storage tanks were encountered when storing acid with a high percentage of HNO_3 because of resulting cracks in the welded seams (HPC [1945]a:1368).

Explosions and Shutdown

On May 12, 1942, a worker failed to release built-up pressure in the fortified blowcase before attempting to run another charge of acid. The subsequent explosion burned the operator badly and eventually resulted in his death on July 14, 1942. On July 13, 1942, word was received from the Chief of Ordnance that all work at VOW was to cease "not later than August 31, 1942" (HPC [1945]a:1366). Just a week later, on July 20, 1942, an explosion occurred at the plant at 3:40 a.m. at the Fortifying and Bi and Tri House (Baldwin 1942:229). The flash from the explosion was reportedly seen 35 miles away in Lexington. Two men were killed and four others were rushed to the hospital. The explosion demolished several buildings and hastened the shutdown of the plant. Production ceased at the plant after this explosion.

Rumors of sabotage circulated throughout the community (Hudson 1993:A8). Some believed that "the Germans" were behind the explosion while others believed that perhaps the explosion was a case of industrial sabotage (George Tolley, National Park Service, interview 1995; Hudson 1993:A8). The litigious climate surrounding the takeover of the plant appears to lend credence to this theory. A Works Accident Report was filed by Hercules ([1945]a:1367) that explained "the reason and cause" of the explosion, but the report could not be located for review for this report.

On September 21, 1942, the facility was closed and the Engineering Department was charged with the responsibility of dismantling the plant. Following instructions from the Field Director of Ammunition Plants, all buildings were razed and any building having any contact with TNT operation was burned. All operating equipment, essential materiel, and general supplies were transferred to ROW, where a TNT line was built (Baldwin 1942:168). By October 1, 1942, all personnel had either been terminated or transferred to various Hercules plants and the real estate had been returned to the care of the United States (HPC [1945]a:1374). The Accounting Department was the last to leave the plant site, ensuring that all work had been completed and all records were sent to Radford. Radford received 63 railroad carloads of materiel, New River received one carload, and Weldon Springs, Missouri, received one carload (HPC [1945]a:1373). Radford's TNT line was built but never used. A new TNT unit was constructed and dedicated at ROW in 1968.

In 1946, the federal government transferred the land to the George Washington National Forest which continues to oversee the land today (George Tolley, interview 1995). Although most buildings were destroyed, the schoolhouse and nine dwellings were left on the site (HPC [1945]a:1973). A National Park Service archeologist, who has performed a cursory survey of the area, states that "there are concrete piers all over the forest from ordnance plant buildings" and that they are "spread out over 20 or so acres" (George Tolley, interview 1995).

SOCIAL HISTORY

Government Land Acquisition and the Local Community

The areas where both the Radford Ordnance Works and the New River Ordnance Plant were built were largely agrarian with both small, subsistence-type farms and larger, more commercial farms. In the early 1900s, the majority of local farms were owner-operated. Accessibility to railroads in the area increased farming for export, notably cattle and truck farming. Cabbage, potatoes, melons, and other produce were shipped out of the area. Commercial dairy farms increased significantly beginning in the 1920s with milk shipped to Roanoke and Washington. By near mid-century most farms specialized in beef, hogs, dairy cattle, or poultry.

Radford Ordnance Works

The Radford Ordnance Works encompassed 4,119.39 acres: 2,402.95 acres on the Montgomery County side and 1,716.44 acres in Pulaski County within the Horseshoe Bend of the New River. Acquisition of land at this site did not come as a surprise to the property owners since much of the land had been under consideration for some type of industrial use since 1938 and Du Pont had held options on several of the tracts.

The original agreement called for Hercules to acquire the land, but because of time constraints and problems gaining options, the QMC handled the transactions. On August 22, 1940, J. J. Quinn of QMC's Real Estate Branch arrived in Radford and contacted all owners of the property to be acquired. By August 26, options on all the land had been obtained. The Radford law firm of Tyler & McConnell was retained to prepare title abstracts (HPC [1945]a:91).

QMC was able to reach agreements as to value with all property owners although only those tracts with clear titles were purchased outright. Parcels with indefeasible titles were condemned. Both tracts purchased for Radford Village, all land in the Horseshoe, and seven tracts in Montgomery County were acquired by purchase. The remaining nine parcels in Montgomery County were acquired through condemnation proceedings. The total purchase price was $516,119.31. The per-acre value of land for ROW averaged $122.00 per acre although prices ranged from a high of $200.00/acre to a low of $17.50/acre. The highest prices were paid for an .85-acre tract from the New River Methodist Church and for the .42-acre Shellville School tract (Table 10; HPC [1945]a:98-99).

On August 27, 1940, the QMC notified Hercules that they had acquired options on all the land with a provision for immediate possession and gave Hercules permission to enter the properties and proceed with construction. The government had agreed, however, to allow property owners to remove existing crops as soon as possible but it did not allow them time for the crops to mature. It also instructed Hercules that "to avoid hard feelings or possible damage claims, it will be appreciated if, in taking possession of the property, damage to crops can be minimized as much as possible" (HPC [1945]a:88).

The land on which the RAAP now stands was farm land with several large farmsteads (Pezzoni 1995; Winter 1995) and at least two cemeteries (RAAP 1943 [revised 1976]:Real Estate Map). No systematic documentation of buildings that stood on the property when it was purchased by the government was found in the RAAP Archives and it appears from early construction photographs that most buildings were immediately demolished. A contract with a local undertaker indicates that the cemeteries were moved but the new location was not given (Anonymous n.d.a:Appendix).

Table 10
Landowners, Acreage, and Purchase Price for Tracts at ROW

Landowner's Name/Tract	Acreage	How Acquired	Consideration
Montgomery County			
Akers, P.R. (Flanagan Tract)	26.01	Condemned	3,500.00
Altizer, Snidow, Spiers (Eskridge Tract)	76.35	Purchased	3,086.13
Bryant, A.J., and E.H. (Shell Tract)	74.25	Purchased	5,000.00
Bryant, N.K. (Shell Tract)	59.85	Purchased	6,463.80
Beck, Lula Belle (Cloyd Tract)	12.15	Condemned	1,740.00
Flanagan, J.T. (Cloyd Tract)	1,145.87	Condemned	148,625.00
Haymaker, B.L. (Eskridge Tract)	248.31	Condemned	19,965.00
Hurt, R.S. (Cloyd Tract)	383.03	Condemned	11,321.60
New River Methodist Church	0.85	Condemned	1,000.00
Price, H. Leffel (Cloyd Tract)	90.82	Purchased	13,168.90
Price, Agnes (Cloyd Tract)	4.40	Purchased	550.00
Simpson, William Roy (Simpkins Tract)	10.15	Condemned	(Estimated) 2,030.00
Simpson, F.F., and W.D.	103.03	Condemned	19,575.00
Simpson, E.W., and C.	58.15	Condemned	3,489.00
Shellville School (Shell Tract)	0.42	Purchased	125.00
Ward, H.S. (Cloyd Tract)	108.95	Purchased	20,347.50
Total for Montgomery County	*2,402.59*		*259,988.43*
Pulaski County			
Flanagan, F.H., and A. Moore, A.K. Flanagan (J. Cloyd Kent Tract)	708.02	Purchased	88,252.50
Sutton, N.B. (Einstein Tract)	348.00	Purchased	48,720.00
Sutton, N.B. (Adams Tract)	412.75	Purchased	61,912.50
Webb, George M.—Heirs (Kent Tract)	132.32	Purchased	21,875.00
Flanagan, Erica (Einstein Tract)	116.35	Purchased	17,743.38
Total for Pulaski County	*1,716.44*		*238,503.38*
Radford Village			
Painter, J.A. et al.	43.85	Purchased	6,577.50
Gilbert, W.E. et al.	55.25	Purchased	11,050.00
Total for Radford Village	*99.10*		*17,627.50*
Grand Total	4,218.13		$516,119.31

Early construction photographs taken from the cliffs on the New River indicate that most of the land where the main manufacturing plant now stands was in pasture with several fields of corn (Plate 4). The Flanagan family owned land here and raised cattle. Area residents remember their cattle drives in the late 1930s to the railroad yards in Radford (Shirley Bruce, interview 1995). The Flanagan barn, an early twentieth-century frame barn, was moved to another site in the area. The Flanagan house, a brick, Queen Anne-style dwelling, survived for several months while it was used as offices for Hercules staff (Plate 5). Photographs of the Cloyd farmstead, located in the Horseshoe, indicate that it had a number of early brick dependencies (Plate 6). (For more information on the preinstallation history of this land see Pezzoni 1995; Winter 1995).

Plate 4. Photograph of the site of the Radford Ordnance Works, taken from across the New River looking southward, showing farmland just as construction began, September 15, 1940.

New River Ordnance Plant

Since it had been well-publicized that the bag loading plant would be built in the Horseshoe area at the main plant, the development of the New River Ordnance Plant near Dublin in Pulaski County came as more of a surprise to area residents. According to one former landowner, little warning was given about the fact that the government was interested in purchasing land in their area (Janie Hardwicke, interview 1995). Similar to the situation at the ROW site, this land was farmland with owners whose families had owned the property for generations. There were at least six family cemeteries on the land that became the NROP (RAAP 1943 [revised 1964]:Real Estate Map). Farmers grew wheat and corn and raised cattle; apple and peach orchards as well were found on most of the farms (HPC [1945]b:29).

Many of the landowners were descendants of settlers who had acquired the land in the revolutionary war-era. The Wygal-Hardwicke farm occupied the northern area of the proposed plant and was probably established by Adam Wygal who purchased property in the area in 1796. This farm had an extensive complex of domestic and agricultural outbuildings that included a two-story frame house, summer kitchen, spring house, tenant house, wash house/schoolhouse, blacksmith shop, cattle barn, horse barn, hay barn, log corn crib,

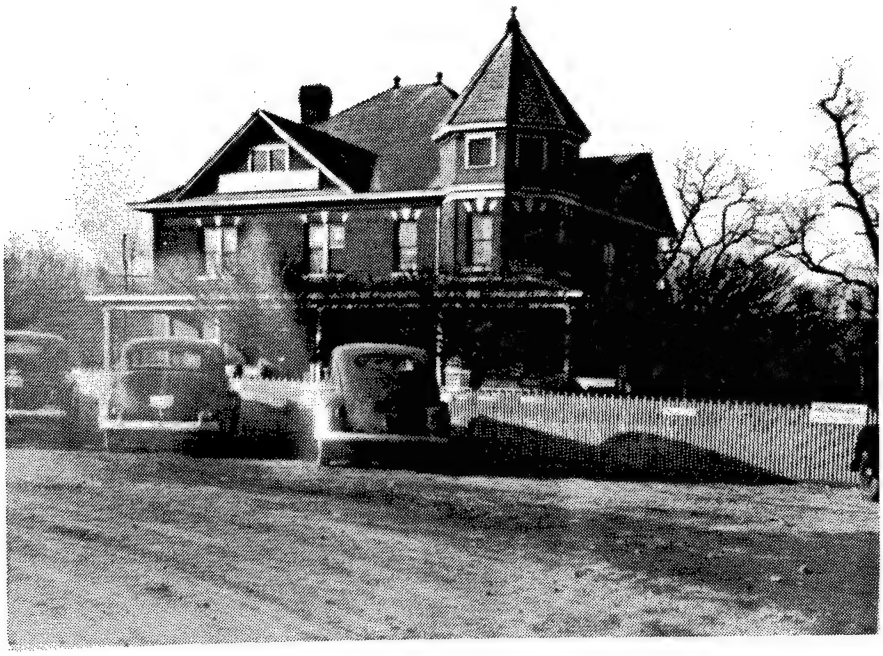


Plate 5. Photograph of the W. E. Flanagan house used as offices at Radford Ordnance Works, September 1940.

Plate 6. Photograph of the Cloyd farm complex that stood in Horseshoe Bend area of Radford Ordnance Works, 1930s.

chicken and turkey houses, and pig pen. The Shufflebarger house stood near what would become the center of the plant on Sinking Spring Branch. It was a two-story, log and frame dwelling sheathed with weatherboards. A picket fence enclosed a large yard with boxwood and shade trees (Pezzoni 1995; Winter 1995). The Sebastian Wygal house was an impressive, two-story brick dwelling. When the land was cleared for the bag loading plant, the house was demolished with explosives (Janie Hardwicke, interview 1995). The Dudley farm was one of the largest that was purchased by the government and was situated on land that would be the central portion of the new plant. It was photographed before construction began, showing plowed fields, pasture, and an orchard enclosed by a worm rail fence (Plate 7).

Acquisition of land for the New River plant began on November 4, 1940, and was handled by the Land Acquisition Division of the U.S. Department of Agriculture. A total of 3,834 acres was purchased by the government (HPC [1945]b:41-42). Many of these owners were reluctant to part with their homes and some felt that they were not adequately compensated. Janie Hardwicke, who was a young school teacher when her family's land was seized by the government, characterized her grandmother as being "stricken" at having to leave the Wygal-Hardwicke farm where she had grown up (Janie Hardwicke, interview 1995).

When construction on the New River plant began in February 1941, work on the ROW was well underway. Workers had flooded into the area, resulting in a severe housing shortage. Many of the landowners who were forced to move but wanted to remain in the area faced crowded conditions and limited options. Miss Hardwicke recounts a desperate situation for her family. They ultimately were allowed to purchase a small tract of government-owned land on which they could build a new house. However, building materials and carpenters were also in short supply. It was only through the efforts of a family of carpenters from West Virginia, who boarded on the Wygal-Hardwicke Farm while they worked at ROW, that the Hardwicke house was built. Not only did they build the new house, they secured all the lumber used in its construction (Janie Hardwicke, interview 1995).

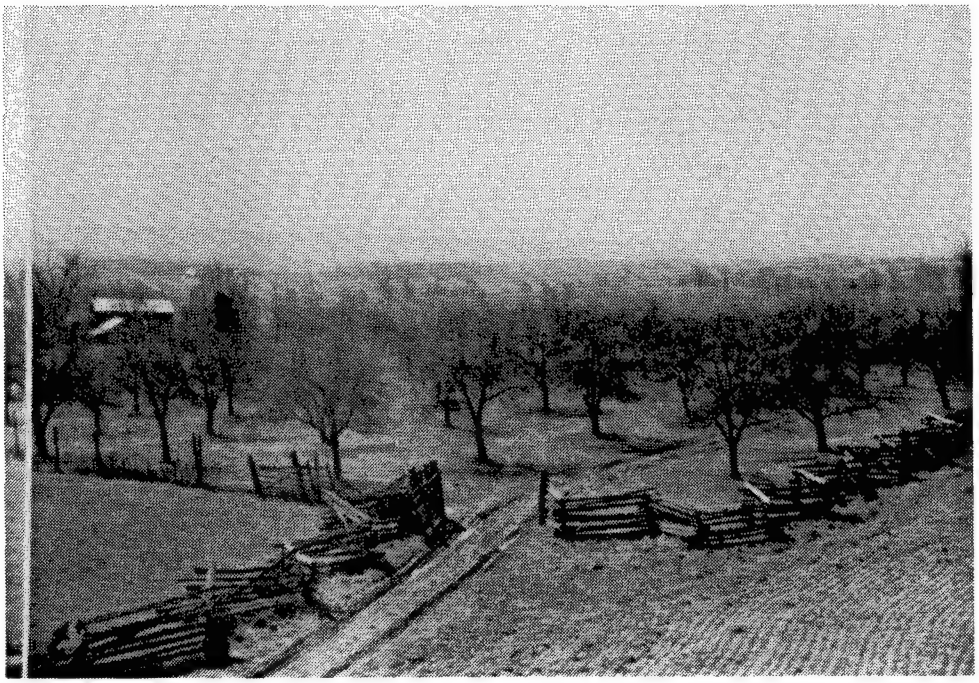
Boom Town Phenomenon

On the national level, the boom town phenomenon that affected all of the communities in close proximity to the immense GOCO plants brought welcome economic stimulation as a result of new jobs. The employment boom occurred initially during the construction period and was followed by seemingly unlimited opportunities for all who wanted to work at the plant. Jobs that had been so scarce during the previous decade of the Depression were now plentiful and at wage rates that had never been experienced before.

On the local level the building of the two plants brought significant changes to the area. The public relations officer at ROW commented on the changes:

> The Radford Ordnance Works caused Radford to become a boom town. People poured into the quiet little community by the thousands, changing the order and character of the town and its people. Trailer camps, boarding houses, and amusement centers sprang up, small homes began to be erected; police forces had to be enlarged and their work more than doubled; more schools and more teachers, meaning a heavier school budget were necessary; highways had to be built, rebuilt and repaired; town and city councils and boards of supervisors found their meetings lengthened by the multitude of problems springing up from the influx of workers (Cord 1954:172).

Milk control boards were set up, rents increased 25 percent and more, school attendance increased 10 percent, water consumption nearly doubled, and local areas were plagued with traffic jams. The Radford mayor appealed for common sense and warned against price gouging. Local editorials welcomed the increased business opportunities and an end to high unemployment (Cord 1954:174). Although local government representatives met with officials from the War Department and Hercules to plan for the construction of the plant, most of the prior planning focused on housing needs and is discussed in a following section of this report.



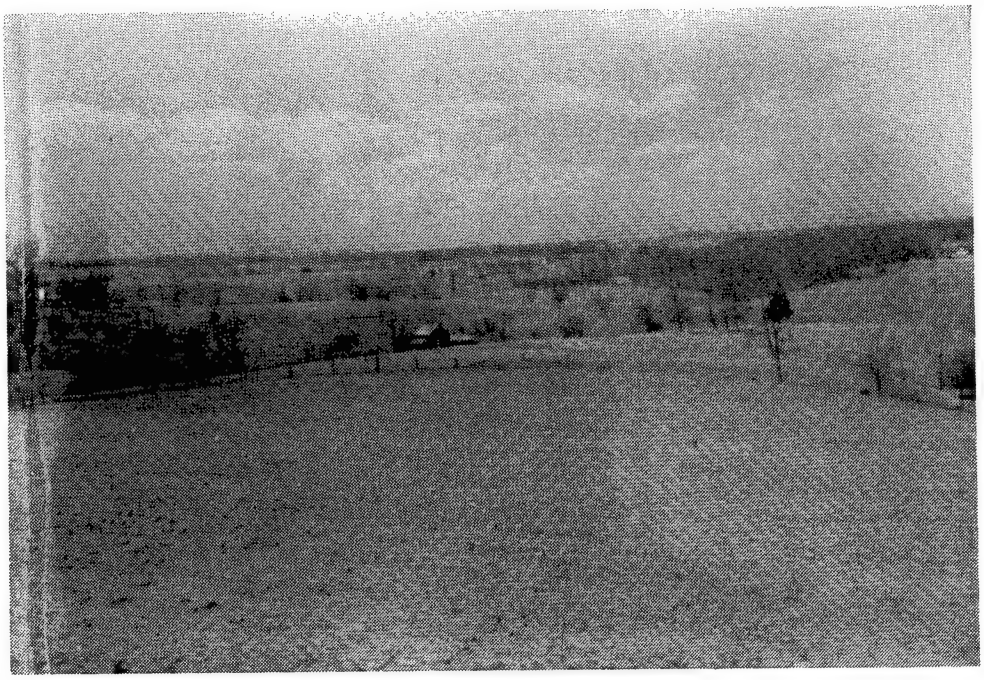


Plate 7. Panoramic view of the Dudley farm, March 25, 1941, site of New River Ordnance Plant.

Construction Workers

The construction of ROW created an tremendous and immediate influx of workers into the area. This flood of workers was described by the local paper as "young and old, skilled and unskilled, married and unmarried" (Cord 1954:171). Initially they were from the local population, but soon workers came from great distances. The majority came from the nearby southern states of Virginia, West Virginia, Tennessee, Kentucky, and North Carolina, but eventually 45 states were represented among the work force (Figure 10; Serrum 1941:547).

The August 21, 1940, announcement in the *Montgomery News Messenger* that a powder plant would be built in Montgomery and Pulaski counties indicated that construction of the plant would take 10 months and employ 5,000 men in construction and another 2,500 in operations (*MNM* 1940a:1). When construction of the bag loading facility was announced in September 1940, it was expected that it would employ 1,500, most of whom would be women. The newspaper also announced that most construction workers would be from other counties or states and were not expected to bring their families (*MNM* 1940b:1).

Mason & Hanger, the construction contractor, organized an employment office in Radford and the first personnel clerk was hired September 19, 1940 (Serrum 1941:546). The employment office was initially housed in the American Legion Building in Radford. As soon as a building could be constructed, the employment office was moved to the plant. Employment rapidly increased during the construction period. On October 5, 1940, there were only 218 employees at the plant. A little over a month later there were 1,600 construction workers (HPC [1945]a:199). By November 16, 1940, there were 3,343 employees. The greatest increase in employees came in mid-February 1941 when 1,851 workers were hired in one week. Although peak employment of 23,150 workers was reached during the week of March 19, 1941, by May employment had dropped by 8,105 (Baldwin 1942:214). When workers first arrived in town, they slept wherever they could. Many slept in chairs at the train station or in the basement of a local furniture store (Johnson 1985:100). Locals began to rent out any available space they had—a spare bedroom, an outbuilding, a basement, a back porch, an attic or even a chicken coop. Because the work at the plant was done in shifts, several men could share the same bed. "A single bed may have had as three men sleeping on it at different times during a twenty-four hour day" (Gross 1991:3).

Because of the scarcity of housing in the immediate area, many workers lived as far away as Roanoke and commuted to the construction site each day. By the end of November 1940, ROW had arranged for buses to transport workers from the towns of Christiansburg, Cambria, Blacksburg, Pulaski, and Dublin. Trains also brought workers to the site. Beginning in January 1941, the Norfold and Western ran as many as five trains a day specifically to transport ROW workers from Roanoke. Other trains ran from Bluefield and Wytheville.

The 1941 written plant history delineates the scale of wages paid to the various trades and classes of labor at ROW during the first phase of construction (Serrum 1941:561). Most laborers, skilled and unskilled, were paid at an hourly rate ranging from a low of 35 cents (unskilled laborer) to a high of $1.50 (shovel, crane, dragline, and derrick operators) (Serrum 1941:561-563). Most foremen and office workers were paid on a weekly or monthly salary scale (Serrum 1941:566-567). Supervising Engineers were the highest paid of the monthly salaried workers at $541.66 and field auditors were next highest at $466.66 per month (Serrum 1941:566). Of the weekly salaried workers, truck foremen and bricklayer foremen were the highest paid at $85 and $75, respectively (Serrum 1941:566-567). Surveyors and rodmen were paid on a daily scale ranging from $3.50 to $15 (Serrum 1941:561). The following chart lists the wage ranges for some common construction classifications (Serrum 1941:561-564):

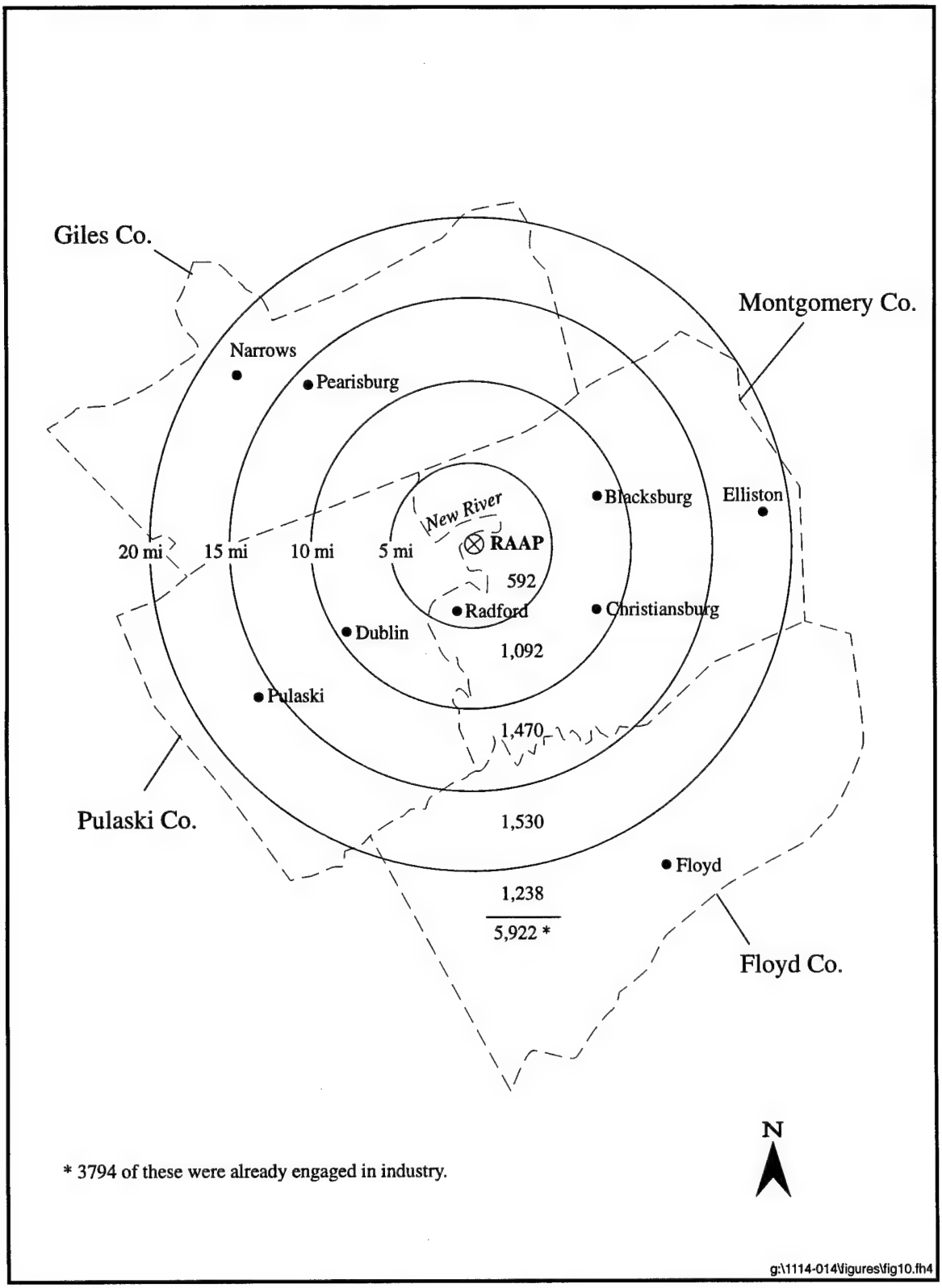


Figure 10. Farm men and women available for industrial employment, Floyd, Giles, Montgomery, and Pulaski counties, December 1940 (after Serrum 1941:423).

Classification	Range of Rate per Hour
Blacksmith	$ .80 - 1.00
Bricklayer	1.25 - 1.375
Boilermaker	1.25 - 1.375
Carpenter, journeyman	.80 - 1.00
Cement worker	.45
Cranes	1.25
Electrician	1.00 - 1.25
Jackhammerman	.50
Labor, foreman	.75
Machinist	.15
Mechanic, first class	.85 - 1.00
Mechanic, second class	.75
Pipe fitter	1.00
Plumber	1.00 - 1.25
Pipe layer	.60
Plasterer	1.10 - 1.25
Sheet metal worker	.90 - 1.00
Steamfitter	1.00 - 1.25
Structural iron worker	1.10 - 1.25
Truck driver	.40 - .60

Per orders from the Quartermaster General, Construction Division, War Department, Washington, D. C., overtime pay rates were fixed at the following: work in excess of eight hours per day would be paid at one-and-one-half times the basic rate and work in excess of 40 hours per week would be paid at one-and-one-half times basic rate (Serrum 1941:561).

Local reaction to the influx of workers was mixed. Although some local residents indicated that they brought unwanted changes to the area, they did not necessarily blame the individuals as much as the situation (Leo Stanger, interview 1995). Others thought that eventually everyone got along together (Alene Graham, interview 1995).

Boom Town Effects on the Local Infrastructure

Housing

Housing the many plant workers was the greatest difficulty encountered with the start-up of the Radford plant. A survey of the rural housing conditions in and around Radford was conducted by the Farm Security Administration, Defense Home Corporation, and the VPI&SU Extension Service. According to Hercules ([1945]a:278):

> As a result of the rural housing survey covering a total of 6,928 farm families, it was found that 2,636 were considered to be inadequately housed. Nine hundred and sixty-nine of these were listed as eligible for and definitely interested in the Federal Government's constructing houses on their property for lease to Radford Plant families during the emergency and for sale when the plant closed or restricted operations. Of this total of 969 houses wanted, 493 were for tenants and 476 for owner-operators. Of this same total, 58 were within 5 miles of the plant; 200, from 6 to 10 miles; 189, from 11 to 15 miles; 163, from 16 to 20 miles; and 357, over 20 miles.

Meetings were also held with the mayors of six nearby towns to establish the possibility of constructing new homes within town limits. It was estimated that the government would need to build 900 to 1,000 new homes to provide for the incoming work force. The preference was to distribute these houses throughout the towns and counties for the benefit of those who remained after the plant's mission was completed.

However, the rural and urban proposals were different matters. Proposed rural housing was basically an individual family decision; the proposed urban housing was a matter for consideration by the town council, which had to provide for sewage disposal, water mains, streets, sidewalks, and lights (HPC [1945]a:278). The area towns, in each case, submitted to the government the total number of houses they could provide within their limits: Pulaski, 150; Dublin, 50; Radford, 500; Christiansburg, 200; Cambria, 50; and Blacksburg, 100 (HPC [1945]a:279). This information was submitted to the federal government for further action, although not all the of the proposed houses were constructed.

Housing for defense workers was built at both ROW and NROP as well as in surrounding towns. The developments of Radford Village, Monroe Terrace, and Sunset Village in Radford and McGill Village in the town of Pulaski were all Federal Housing Authority projects. Other housing developments sprang up as private ventures and included Fairlawn, Leehigh Court, Victory Heights, and Airport Acres (Table 11). All of these housing projects still exist today.

Table 11
Housing Facilities Constructed Primarily for Defense Workers

Primarily for Radford Plant Personnel	
Built by Mason & Hanger at the time ROW was built	*Total*
Government Village (Staff Residences), plant site	16
Radford Village, West Radford, Virginia	43
Barracks, plant site	7
Built by Defense Homes Corporation (U.S. Government)	
Monroe Terrace, East Radford, Virginia	93
Built by Federal Public Housing Administration (Government)	
Sunset Village, West Radford, Virginia	129
Rural Homes	31
Built by Private Concerns	
Fairlawn, between Radford, Virginia, and Plant	150
Leehigh Court, Christiansburg, Virginia	33
Victory Heights, Christiansburg, Virginia	20
Freedom Homes (Airport Acres), near Blacksburg, Virginia	60
	582
Primarily for New River Plant Personnel	
Built by Mason & Hanger at the time plant was built	*Total*
Staff Residences, Plant Site	15
Built by Federal Public Housing Administration (U.S. Government)	
McGill Village, between Pulaski and Newbern, Virginia	15
Rural Homes	75
Barracks, just off plant site	20
	125

Source: HPC [1945a]:283

Sixteen, two-story Colonial Revival-style houses were constructed just southwest of the plant site as part of the original contract with Hercules (Figure 11). Mason & Hanger completed the construction. Four of these houses were duplexes. Hercules officials and Army officers of the War Department occupied these units. The estimated cost of the project was $300,000 (HPC [1945]a:284). These houses still stand and currently house government personnel at RAAP.

The plant provided barracks for some of the many workers who flooded into the Radford area. Seven concrete block barracks were constructed on the southeastern side of the operations area (HPC [1945]a:285). Each building had a capacity of 104 men and consisted of 24 single rooms, 32 double rooms and four odd-sized rooms (HPC [1945]a:688-689). A 10-stall toilet room and a six-stall shower room were located in each building. The rooms were furnished with a bed, pillow, and mattress, and a desk, throw rug, trash can, radio and magazine table, chairs, drinking glasses, and ash tray (HPC [1945]a:689-690). The windows were screened and each room had a radiator. Janitorial services were supplied and a linen service was available at a fixed price. Rent was set at $10 per person for double rooms and $12 per person for a single room (*RPW* 1941j). At first, the barracks were for men only and were restricted to civilian employees of the War Department and to the operating force from Hercules. Total cost for all seven barracks was $490,000.

The first two barracks buildings were completed as offices for Hercules and the War Department on December 9, 1941. Previous to completion of these buildings, these staffs were located at the American Legion Building in Radford. Half of the No. 5 barracks was used for offices and the other half for storage until October 1941. No. 6 barracks was redesignated for women in February 1943 and another barracks was designated for women by the end of 1944. The barracks were ready for employee occupancy on the following dates (HPC [1945]a:697):

No. 1 opened in September 1942
No. 2 opened in December 1941
No. 3 opened in January 1941
No. 4 opened in February 1941
No. 5 opened in January 1942
No. 6 opened in July 1941
No. 7 opened in April 1941

The barracks were filled to capacity from September 1942 to April 1943, since at that time Radford was training men for other plants. Again in August 1944 the barracks were full to capacity as new employees were hired and in early 1945 employees from the New River plant were housed in ROW barracks (HPC [1945]a:704-705). In March 1945, a new construction campaign was started to build new two-story barracks and to place a second story on six of the existing barracks buildings; only three, however, were completed before the end of the war (HPC [1945]a:706).

Fifteen houses for plant officials were constructed on the New River Ordnance Plant. Of these, seven were eight-room houses, five were seven-room houses, and three were six-room houses. Mason & Hanger was responsible for construction of these frame houses, which were valued at $25,000 each (HPC [1945]a:286). They were two-story, Colonial Revival-style houses similar to those built at ROW. These houses are still standing but are now privately owned (Plates 8, 9, 10).

Government Ventures

Radford Village (Figure 12; Plate 11): One hundred new houses were proposed for the 98-acre Radford Village in West Radford. The houses were to be for key officials of the Hercules Powder Company, with a purchase price set between $4,000 and $8,000 each. The government purchased the land, but the City of Radford provided all utilities. The firm of Carneal, Johnston & Wright Architects of Richmond was

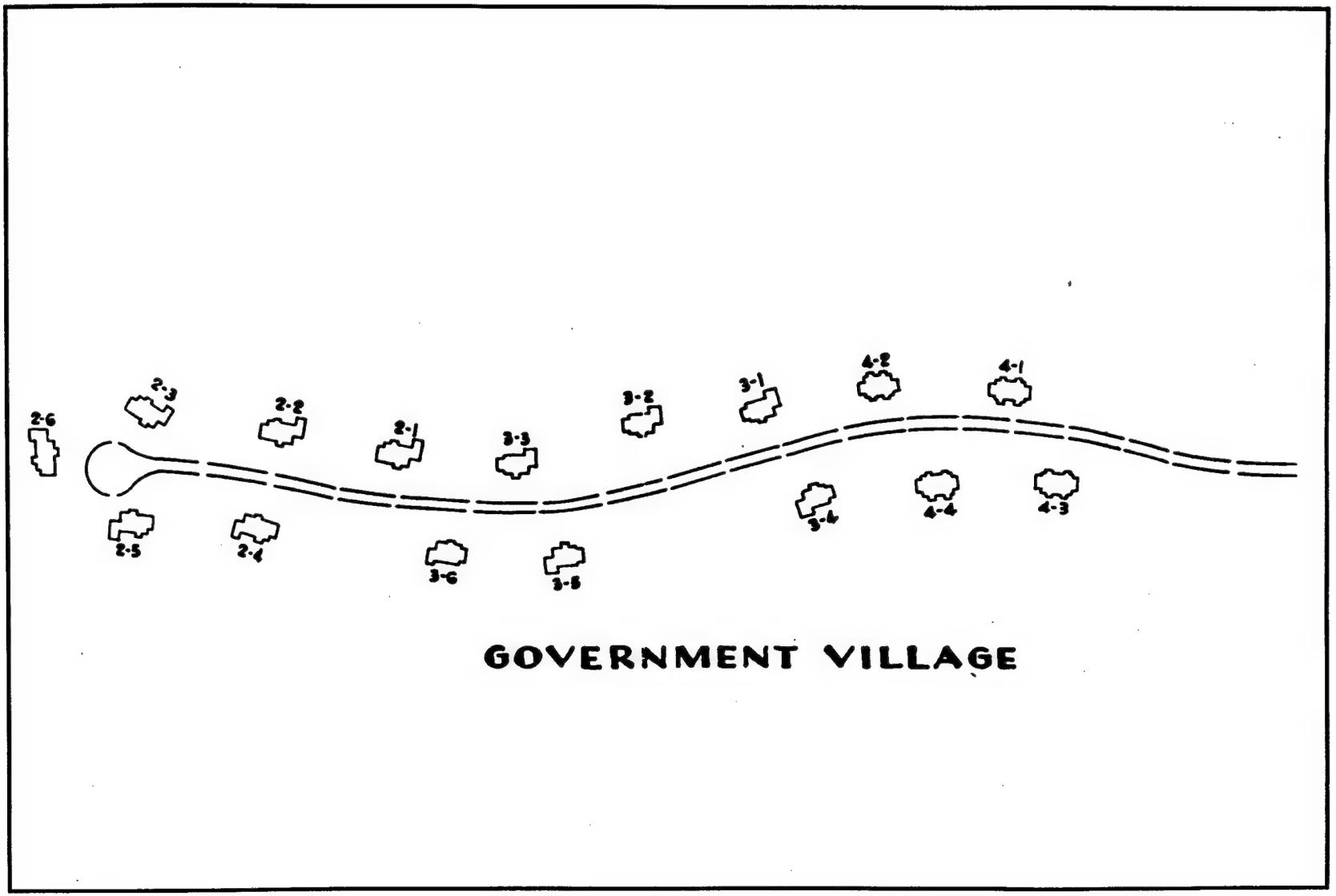


Figure 11. Layout of Government Village, Radford Ordnance Works.

Plate 8. New River Ordnance Plant Staff Village, January 2, 1942.

Plate 9. New River Ordnance Plant Staff Village, February 1995.

Plate 10. Individual House at the New River Ordnance Plant Staff Village, February 1995.

contracted to design these houses, with Mason & Hanger to begin construction at the same time as the plant was begun. A shortage of skilled labor delayed the project, however, and the number of units was reduced to 43 in May 1941. The houses were ready for occupancy by that September (HPC [1945]a:284).

Monroe Terrace (Plate 12): During the summer of 1941, 93 houses were built in East Radford for monthly rental to the defense workers and government employees at ROW. These houses were built under the auspices of the Defense Homes Corporation of the federal government (HPC [1945]a:285).

Sunset Village (Plate 13): The Federal Public Housing Administration constructed 129 houses in West Radford in July 1941. Of these, 98 were four-room houses, 30 were five-room houses, and there was one five-room Community House. The frame houses rented from $24 to $28 a month. The average construction cost of each house was $4,000 (HPC [1945]a:286).

McGill Village: The Farm Security Administration built 75 duplex houses in the town of Pulaski during the spring of 1941. Barger Brothers Construction Company was responsible for the construction of these houses. The average construction cost of each was $2,854 (HPC [1945]a:287).

Rural Homes: Thirty rural homes were also constructed in Pulaski County and were rented on a monthly basis with rates ranging from $13 to $50, depending upon the wages of the occupant and the number of children in the home. At the end of the war, these four- or five-room houses were sold to the landowners on whose land they were constructed, less depreciation (HPC [1945]a:287).

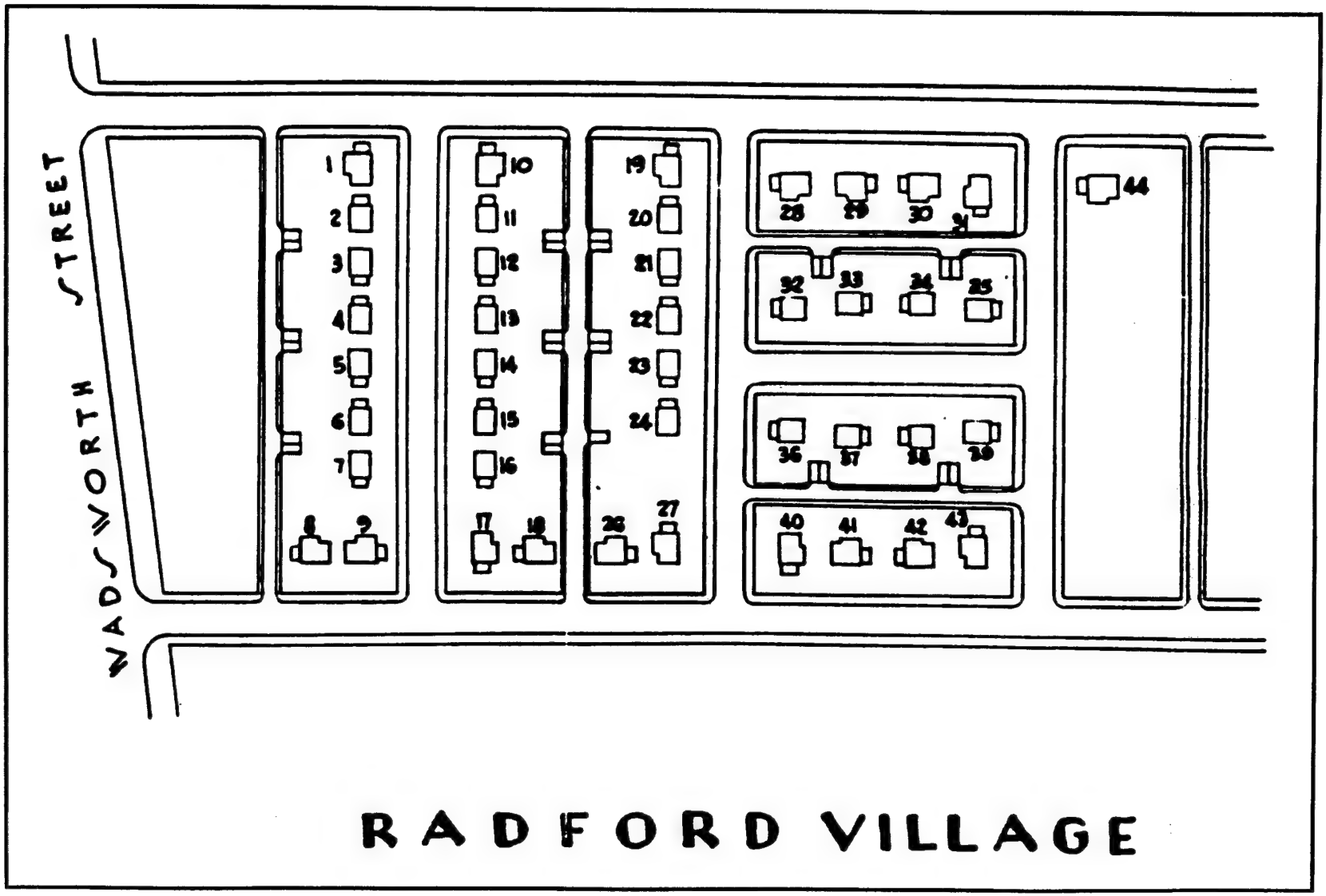


Figure 12. Layout of Radford Village, Management Housing in Radford, Virginia.

Plate 11. Houses at Radford Village, Radford, Virginia, February 1995.

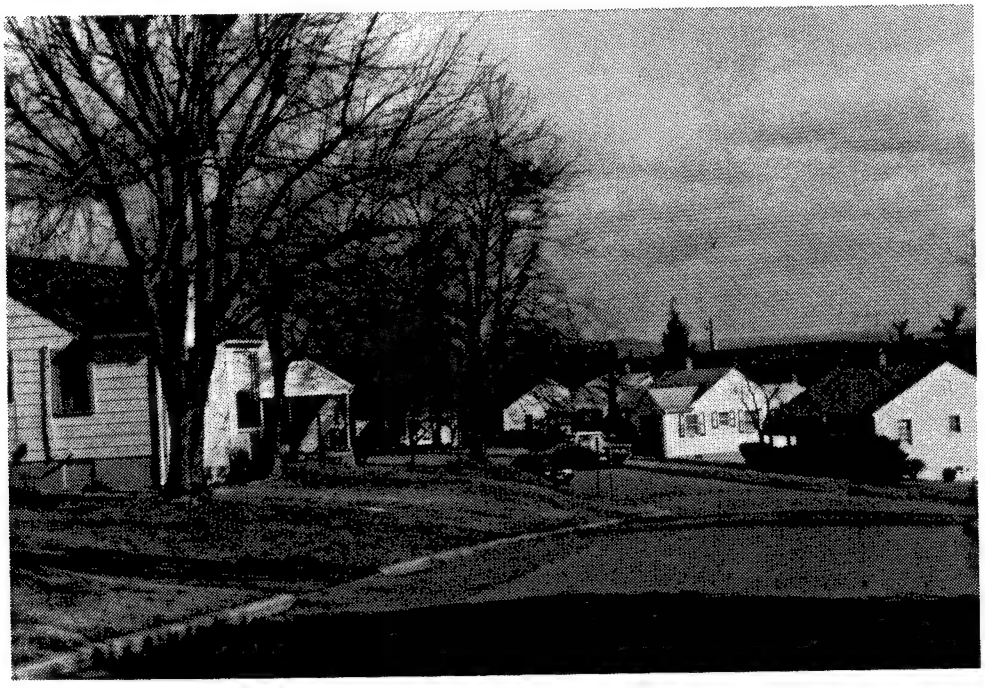


Plate 12. Houses at Monroe Terrace, Radford, Virginia, February 1995.

Plate 13. Houses at Sunset Village, Radford, Virginia, February 1995.

Private Ventures

Fairlawn, in Radford, was a privately constructed community of approximately 150 houses. Constructed at a rapid pace in 1942, the typical Fairlawn house had "a small kitchen, a small den, one or two bedrooms downstairs, a loft upstairs, one bathroom and a tiny dining space" (Figure 13 and Plate 14; Turner 1991:3). The "five-room colonial bungalows" at Fairlawn were advertised for $2,990 and the smallest lot was one-quarter of an acre (Fairlawn Realty Co., Inc., 1942). Attractive features such as oak floors, chromo-tile, closets, oil furnace, water heater, electric range, large living rooms, and deluxe kitchen were highlighted. Claims were also made for "fine materials throughout, A-1 workmanship, lawns seeded and shrubs planted" (Fairlawn Realty Co., Inc., 1942). Prior to the construction of Fairlawn, the land had been an apple orchard. Since landscaping was not completed when the residents began to move in, the area has been described as "bare" (Greenberg 1991:6).

Most of these houses have had additions constructed over the years, with the most common additions being porches, additional bathrooms, and larger dens. Although touted by the realty company for their fine materials, the frame houses reportedly will not keep paint and one present-day resident believes this is "because the lumber that was used [during construction] had not been dried out enough because the builders were in such a hurry" (Turner 1991:3). Thus, many of the Fairlawn residents have had aluminum siding installed on their homes.

Other private housing developments included 20 houses in Victory Heights and 33 houses in Leehigh Court (spelled "Leehy" on street signs) in Christiansburg (Plates 15, 16). The Leehigh Court houses could be purchased for a downpayment of $175. Identical to those constructed by the FPHA at Sunset Village and by the Defense Homes Corporation at Monroe Terrace, these houses were advertised as "designed and built especially for Hercules workers only, according to F[P]HA plans and specifications" (*RPW* 1943e). The 66 houses at Airport Acres in Blacksburg were also built according to FPHA plans.

FAIRLAWN HOMES

Open for Inspection Daily, Afternoon and Evening

Finer construction . . . better architecture . . . and more spacious floor plans at prices wthin the moderate income.

Five-Room Colonial Bungalow

F.H.A. INSPECTED AND APPROVED

$2990.00—$190.00 DOWN PAYMENT—$23.50 PER MONTH, INCLUDING PRINCIPAL INTEREST, TAXES, AND FIRE INSURANCE

--CONSIDER THESE FEATURES--

Fine materials throughout	Bath with built-in fixtures
A-1 workmanship	Oak floors throughout
8" foundation on 14" concrete	Chromo-tile in bath and kitchen
Concrete walk and steps	Large closets with rods and shelves
Large front porch	Disappearing stairway to floored attic
Moisture and fire-proof storm siding	Norge oil furnace
Wide cypress siding	Hot Point electric range
3 coats Sherwin Williams paint	Hot Point electric hot water heater
Weather stripped doors	Electric heater in bathroom
Spring cushioned windows	3 built-in cabinets in kitchen
Bird blended roofing	Musical door chimes
Rear service entrance	Sergeant hardware
Colonial front door	Ample electric outlets
Shutters on front	Lightolier light fixtures
Lawns seeded	Inside trim—white pine
Shrubs planted	Finished with DuPoint's enamel
Large living room	Side walls papered or painted
Cozy dining room	Stippled ceilings
Two bedrooms	Appalachian current
Deluxe kitchen	Low county taxes

THE SMALLEST LOT 75x160—OVER ¼ OF AN ACRE

For additional information regarding Farlawn Homes see—

Fairlawn Realty Co., Inc.

Belspring and Pepper's Ferry Roads

Just across the River In Pulaski County

Radford, Virginia; Route No. 2 Phone Radford—624

Figure 13. Advertisement for Fairlawn Homes.

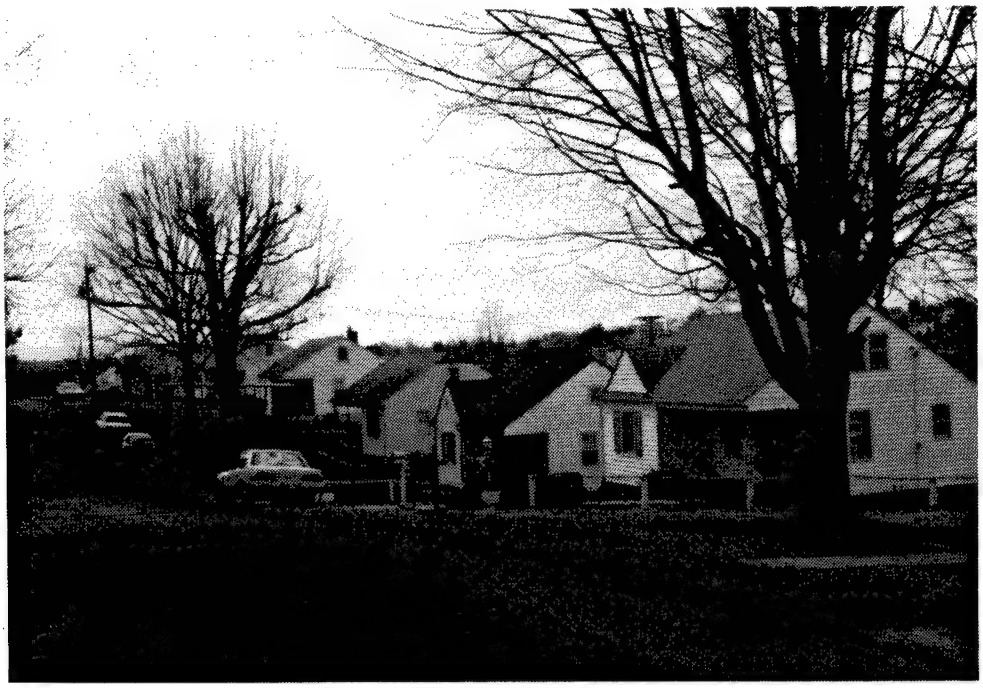


Plate 14. Houses at Fairlawn, Radford, Virginia, February 1995.

Plate 15. Houses at Victory Heights, Christiansburg, Virginia, February 1995.

Plate 16. Houses at Leehigh Court, Christiansburg, Virginia, February 1995.

Other Housing

In September 1942, construction and enlargement of ROW continued. It was necessary to locate additional housing in the area and, therefore, the Homes Registration Board (HRB) at the ROW was organized (HPC [1945]a:282). The HRB was responsible for locating and keeping records of available houses and rooms for rent in the area and inspecting these sites for desirability, including "sanitary conditions and moral surroundings" (HPC [1945]a:282). The HRB was also responsible for recording all housing requests submitted by the plant personnel. The HRB was discontinued on June 30, 1943, since it was felt the decrease in employees and available number of houses in the area indicated that it was no longer needed. However, with the increase in recruitment in 1944, the HRB was reestablished with the same basic responsibilities. Advertisements were placed in newspapers to again survey available housing in the area. The HRB's functions virtually ceased in January 1945 because most available housing had been rented (HPC [1945]a:298). Plant dormitories were filled to capacity during 1945 and family accommodations were almost impossible to obtain.

Local Infrastructure

The rapid increase in population placed stresses on local governments to keep pace with increasing demands. To help manage the near-crisis atmosphere in Radford, a variety of new committees, boards, and services were established, some of which were able to tap into federal aid for a variety of projects. A new water filtration plant that furnished 2,000,000 barrels of water daily was constructed in 1943 with funds from the Federal Works Agency. Radford also received funds through the Lanham Act to build a new hospital. On May 16, 1942, the Recreation Building (Plate 17) was dedicated as a wartime federal facility, which was made necessary by the population increase resulting from the construction of ROW. The public library was housed in this building as was a day-care center for the children of women working at ROW during the latter

Plate 17. Recreation Building, Radford, Virginia, February 1995.

stages of the war. By the end of the war, Radford had also enacted a new zoning ordnance to control and direct growth (Johnson 1975:57-59).

Effects on Local Economy

The influx of construction and production workers created many new economic opportunities. New retail establishments, particularly groceries and restaurants were begun to meet the needs. Housing construction increased dramatically to provide sufficient homes. The Norfolk & Western Railway reported a 264-percent increase in ridership during 1941 (Cord 1954:172).

Shortages of labor affected local businesses as well as ROW. Since ROW paid higher wages, it became difficult to get workers in some retail establishments—particularly grocery stores and service stations. Many young people left the part-time jobs they had held during their school years to work at ROW as soon as they turned 18 years old. Alene Graham fit that pattern (Alene Graham, interview 1995).

Organized Labor

Historically the South, and in particular this region of Virginia, was not heavily organized by labor unions, with the exception of coal miners. Although there appear to have been a number of small strikes and jurisdictional disputes at both ROW and NROP, there was no information in the plant histories that indicated major problems with organized labor nor that indicated how strong unionized labor was as the plant. Construction workers seem most likely to have been labor union members during the construction of ROW and NROP.

Information available from the RAAP archives indicates that from November 9, 1940, to June 24, 1941, meetings were held about twice a month (although several months were skipped entirely) between union representatives and management representatives from both Mason & Hanger and Hercules on a variety of issues, including organization of workers, wage rates, and the shortage of skilled workers. The unions represented included the Bricklayers International Union, International Engineers and Operators Union, Boilermakers Union, International Bridge Structural & Ornamental Iron Workers, International Brotherhood of Electrical Workers, International Plumbers and Steamfitters Union, and the Buildings Trades Council of Richmond, Virginia (HPC [1945]a:166-177). The first meeting occurred November 9, 1940, at the Dixie Inn in Radford (HPC [1945]a:166-168). Union efforts to organize workers were hampered by not being allowed to solicit members within the plant grounds. It was difficult to interest employees outside the gates on their way home after a shift and union organizers were constantly trying to have this restriction removed (HPC [1945]a:167).

On February 12, 1941, Mason & Hanger and Hercules representatives met with representatives of several of the above unions and with a conciliator from the U.S. Department of Labor. They agreed that there would be no organizing activities on the plant site, there would be no closed shop, and that Mason & Hanger and Hercules would attempt to fill their requirements with union workers. The unions agreed to supply workers within 48 hours of a request (HPC [1945]a:168). After the meeting, it was determined that the wages offered were below what the unions would accept. Union representatives endeavored to have the wage rates increased since it was difficult to obtain qualified craftsmen in sufficient numbers. War Department approval was required for a wage increase and Hercules, Mason & Hanger, and the unions presented comparison information on other construction job rates to the Labor Department in Washington. Although action on the matter by the government was slow (HPC [1945]a:169), it appears that an increase in wage rates had been granted by April 29, 1941 (HPC [1945]a:170-171).

Several unions attempted to organize production workers ROW. In January 1945 an election was held to determine which union, if any, hourly workers wanted to join. The unions participating in the election included the A.F. of L., the C.I.O., and District 50 of the United Mine Workers. In the election conducted by the National Labor Relations Board, the A.F. of L. received a majority of votes. With 6,230 employees eligible to vote, the results of the slightly less than 5,000 who participated in the vote are as follows (*RPW* 1945a:1):

No Union	1,784 votes
A.F. of L.	2,194
Dist. 50, UMWA	623
C.I.O.	313

A run-off election between the two groups receiving the highest number of votes—no union representation and A. F. of L.—was then scheduled to be held. Although no record of its outcome was found during research for this project, a later reference indicated that Radford and Badger operated under a single union during the war (Williams 1951).

Hercules officially remained neutral during the election process and urged all eligible workers to vote. It did point out, however, that the federal government controlled all wage increases and that regardless of whether a union represented the workers or not, a raise could not be obtained without the approval of the War Department or the War Labor Board. It also noted that those who joined the union would have to pay dues and that the company could no longer deal individually with the worker (*RPW* 1945a:1).

The NROP was not constructed under an agreement with a labor union. Only two trades, the bricklayers and operating engineers, had union agreements with Mason & Hanger. Other trades apparently attempted to organize the site, but were unsuccessful (HPC [1945]b:111). Late in the war, NROP rejected union representation in a vote.

Work Force Employed During the Wartime Operations Era

During the early years of the war, the need for a construction force at the installation continued. According to Hercules ([1945]a:269), as "[t]he local supply of skilled workers soon became exhausted, so it became increasingly necessary to depend largely upon the U.S. Employment Service for these workers." Therefore, specific requests were issued to all states east of the Mississippi, and in some cases, nationwide, for carpenters, welders, riggers, painters, and millwrights. With this cooperation between employment offices, there was little difficulty in finding the necessary supply of construction workers through 1943. In April 1941, a survey of plant employees revealed that 45 states and 22 nationalities were employed in the Mason & Hanger work force. Although all were U.S. citizens, natives of Canada, Norway, Sweden, and Italy were among the plant workers represented (*RPW* 1941e).

When the operations phase began in April 1941, the majority of the personnel were still construction workers employed by Mason & Hanger. In June there were 827 operations employees and 14,706 construction workers. It was not until October 1, 1941, that the number of people employed in operations (4,873) was greater than the number employed in construction (3,608) (Baldwin 1942:220). By the end of 1941, employment stood at 908 in construction, 6,387 working for Hercules, and 343 government personnel (Baldwin 1942:226).

As the war continued, men, the traditional production workers, were being drafted into the military in increasing numbers and by late 1943 there was an acute labor shortage. The need for workers created opportunities that allowed women and African Americans to hold jobs that had previously been denied them (HPC [1945]a:1186). According to the plant newspaper, one of the major advances attributed to ROW was that Radford was the first plant in the smokeless powder industry to employ women in production on a large scale (*RPW* 1945h:2).

Although the plant histories include little information about women in the work force, the plant newspaper articles indicate that women initially served in traditional roles such as mail clerks, department teletype operators, and administrative receptionists (*RPW* 1942c:4). Women were also employed in the plant hospital as nurses. But by April 1942, women were being transferred from NROP to serve in defense operations-related work at ROW. Editorials urged the men at the plant to accept the women into their ranks and to "show them by our actions that we recognize and respect their effort" (*RPW* 1942d:2). Resistance to hiring women came from some who assumed that women would request special treatment, but the opposite seems to have been the case. Women conducted themselves according to the codes set for men, including the amount of work expected from every employee. Edith Brown, the first woman hired in operations as a replacement for a man, explained that "the men treated us like queens for the first few days, but they're used to us now. We'd rather have it this way . . . none of us expect or want any coddling" (*RPW* 1943j:1).

By October 1942 the labor shortage had increased, resulting in more and more women working in U.S. ordnance plants. A nationwide association, Women Ordnance Workers (WOW), was organized (*RPW* 1942f:1). The increase in female workers at Row necessitated that two of the barracks that had been for men only be redesignated as facilities for women. No. 6 Barracks was the first readied, with a housing capacity for 100 women. The rooms were the same as the men's rooms, but several of the front rooms were converted into a reception area for guests (*RPW* 1943d:1). Several of the single women workers moved into the barracks to lessen their housekeeping and cooking tasks on top of their day-long work at the plant. Moving to the barracks also saved on living and transportation expenses (*RPW* 1943h:4).

Women workers served as representatives of the plant in highly visible sectors. Photographic posters of men and women performing their operations work were used as part of the "Keep 'Em Shooting" production

promotion campaign, described in greater detail later in this report (*RPW* 1943b:4). Like "Rosie the Riveter," the WOWs pursued jobs traditionally performed by men, and excelled in them. One woman was moved in as an increment weigher in Rolled Powder and a year later she was a house foreman in the department in charge of 40 women workers (*RPW* 1943j:3).

The women who filled the positions at ROW came for a variety of reasons. Even though the wages paid to women were consistently lower than those paid to their male counterparts, some women, nonetheless, were drawn to the plant for the wages. The management had established a minimum pay rate of 57.5 cents for male workers, which was "considerably above the going rate for female workers in industry" in the region (HPC [1945]b:315). As late as 1943, however, women were paid 10 cents an hour less than men in the same positions (HPC [1945]b:319). The minimum wage rate established for female workers was 40 cents, with progressive increases to 45 and 50 cents, depending upon the amount of production achieved by the employee (HPC [1945]b:316).

Other women came to work at ROW because a brother, father, or fiancé was serving in the war and the women saw ordnance production as a way to aid these men. Edith Kitts was one of these women and stated that "[w]orking here makes me feel closer to him somehow. I'll never forget how thrilled I was when he wrote me that he was so proud of me working in a war plant. Imagine, him, a soldier, being proud of me" (*RPW* 1943a:3).

The employment of women also resulted in improved safety records at ROW and at other ordnance plants that hired women. Colonel T.C. Gerber, Army Ordnance Director of Safety, stated that "[w]e have found that with the ever-increasing percentage of women in explosive plants, the safety records have improved in proportion to the number of women employed." He skeptically stated that he was "not prepared to say whether this is directly attributable to the employment of women," but admitted that ". . . it is statistically true" (*RPW* 1944c:1).

German prisoners of war were also used because of the labor shortage at ROW. In May 1943, approximately 600 POWs were housed at the plant in a camp (HPC [1945]a:323) that consisted of tents set on concrete pads. The camp was located on the eastern side of the reservation in what locals referred to as "Coffee Pot Bottom" on the former Hurt property near Strouble's Creek (Leo Stanger, interview 1995). The camp, enclosed with barbed-wire, was guarded by U.S. Army personnel (*RPW* 1945c:2).

The POWs performed a variety of duties that included sodding the new Rolled Powder Area, maintaining a construction warehouse, and participating in construction-related work at the New River plant (*RPW* 1945c:2). For the most part, the prisoners caused no trouble at the plant. Former employee Leo Stanger (interview 1995) recalls that as a canteen boy he befriended a couple of the POWs. As he walked back from the canteen, he would sneak "a five-cent cookie" to one of the prisoners, who showed him pictures of his family.

By 1944 and continuing until the end of the war, the labor supply within 100 miles of Radford was very limited (HPC [1945]a:291). To fulfill the need, the company reduced its general standards for employment. In the spring of 1944, with increased production and new construction at the plant, recruitment efforts were needed to supply the necessary labor. In May, recruitment investigators were sent to the nearby communities of Roanoke, New Castle, Floyd, Hillsville, Galax, and Wytheville, and later to almost all employment service offices west of Richmond and selected offices in Maryland, West Virginia, and North Carolina (HPC [1945]a:292).

Recruitment efforts were also underway on the installation itself. All employees were urged to recommend any able-bodied person they knew who was available for employment. In July 1944, a cash bonus was given to employees who successfully recruited workers for the plant. Former employee Alene Graham (interview 1995) who worked in the payroll department remembers that the company paid "three to five dollars" to

employees for each new recruit. Advertisements were placed in newspapers at the beginning of recruitment and efforts expanded to include "handbills, the *Radford Plant Weekly,* Fire Power Caravan, radio, sound truck, billboards, express truck posters, car cards, and movie trailers" (HPC [1945]a:293). Finally, an advertising agency from Roanoke was hired to handle advertising for the plant.

Toward the end of the war, many people began to leave their positions at the plant to return to their peacetime professions or to take higher-paying construction jobs. Officials warned that this optimism was premature and that the forces still needed the ammunition supplied by the plant. The plant newspaper printed admonitions to those who left early: "Stay until the job is finished. Be a stayer! Don't be a quitter!" (*RPW* 1944d:2).

With the 1944 shortage of white workers, both male and female, the decrease in the work force at the New River and Radford installations had become acute. Prior to this time most African-American workers had been involved in janitorial or menial labor jobs at both plants (Alene Graham, interview 1995). It was decided to operate one of the lines at New River with African-American workers. Thus, in December 1944 African Americans were employed in production work at New River and by January 1945 there were approximately 800 African-American workers involved in production. One 105-mm line was operated entirely by African Americans on a three-shift basis.

Although no problems were recounted, Hercules qualified its judgement of African-American capabilities, saying that "[i]t is impossible at this time to give any definite facts regarding the production attained or the effects of the use of colored workers on this type of work" (HPC [1945]b:167). According to Hercules, one of the biggest problems experienced was to provide for the segregation of African Americans within the existing physical plant that was required by Virginia law. To comply with these laws, the hospital basement had to be remodeled to treat African Americans requiring medical attention (HPC [1945]b:211).

Everyday Life at ROW

Training

When Hercules had signed the contract with the government for ROW, it needed to fill key personnel positions quickly. For the construction phase, this was not a difficult task, for the engineering and construction departments of Hercules provided ample experienced personnel. There were, however, fewer experienced, available persons for the operations of the smokeless powder and acid departments. Therefore, the 60 top key positions at Radford were filled with men from the Hercules Powder Company and its existing plants (HPC [1945]a:115). Men were brought in from Kenvil and Parlin and from other companies where nitric acid was being manufactured. For example, the appointed manager for ROW had been a smokeless powder supervisor during munitions manufacturing in WWI and served as manager at Kenvil (HPC [1945]a:115). The assistant manager selected for ROW had experience in acid and dynamite production and had served as superintendent of the Kenvil plant and superintendent of a dynamite plant (HPC [1945]a:115).

For those men who had some experience in ordnance work, refresher courses were set up. For those who only had basic knowledge, full training courses were developed. These training schools were set up at Hercules' Kenvil and Parlin plants, depending on the trainees' projected lines of work. At Kenvil, courses were offered for laboratory and line chemists, for smokeless powder production supervisors, for foremen, and for a limited number of operators (HPC [1945]a:116). At Parlin, courses were offered for chemists and line men in NC and acid production. These refresher and training courses lasted from six to 12 weeks and consisted of practical work, observation of regular employees at work, and classroom work on theories and company policies. The courses were taught by the plant management (HPC [1945]a:116).

Hercules officials visited several colleges and universities seeking qualified chemists and engineers willing to work in the ordnance plant and when the news was released that Hercules had signed a contract for such a plant, the home office received many letters from men who had manufactured smokeless powder during WWI. This gave Hercules a great pool of experienced, mature men from which to choose (HPC [1945]a:116-117). Those chemists and chemical engineers chosen as supervisors were sent to either Kenvil or Parlin for basic training, but also received three additional months of training in supervisory methods. In total, 350 men were trained at Kenvil and Parlin and sent to ROW as needed (HPC [1945]a:117). It became clear, however, that additional men would be needed as production increased. These men were subsequently trained at ROW.

From 1941 through the first part of 1943, the Technical Department at ROW was responsible for training the laboratory staffs working a Hercules' three other ordnance plants—Volunteer, Sunflower and Badger. Although some of ROW's supervisors were transferred to these plants, additional personnel were trained in operations and then sent on to their respective plants. In 1941, a training program was set up under which the operating personnel for the Acid Plant at Volunteer were being trained at the Acid Plant in Radford. There were also trainees involved with TNT laboratory techniques who trained at the Virginia Ordnance Works in Glen Wilton (HPC [1945]a:850).

Other training, which took place at ROW, began with an orientation lab. The trainees were then "farmed out" to other parts of the plant with specific projects or problems to solve and to observe operating employees. This served a dual purpose since the trainees would not only complete their assigned tasks, but they could also become familiar with the plant (HPC [1945]a:829). Approximately 315 men were trained through this course (HPC [1945]a:829). The training program was concluded in May 1943 (HPC [1945]a:830), for during 1943 only 16 new employees came into the technical department, 12 of whom were safety inspectors (HPC [1945]a:830).

Technicians were another group to receive training at ROW. These employees often had basic chemistry skills, but were primarily nontechnical workers who performed a variety of tasks in the operating departments. Radford was the first GOCO plant to hire a large number of women for these positions. Early on, Radford officials began to turn to women because so many men were being drafted out of the technician corps. At the end of 1943, there was a ratio of 3.1 women per man in the technical department (HPC [1945]a:830-831).

During May and June 1944, a training supervisor was appointed to coordinate Job Relations Training Classes, Job Relations Training Review Conferences, Explosives Safety Training and to promote interest in special training courses offered at VPI&SU (HPC [1945]a:295).

Production Efficiency and Safety

On November 13, 1940, the first issue of the Radford Ordnance Works plant newspaper, the *Radford Plant Weekly*, was published by the Safety Department (*RPW* 1943m:4). As originally conceived, the paper was to be used as a safety program and was intended to inform the workers of hazards on the job. Ultimately, however, the paper became more social, including jokes and stories from former ROW workers who had been inducted into the armed services. A variety of information found in these newspapers has been especially helpful in the research for this report.

The first issue of the paper was a three-page mimeographed sheet and 3,000 copies were printed. Soon 10,000 copies were being mimeographed and stapled together. On February 12, 1941, printed issues of the paper were produced by Charles Dyer, a newspaper printer in Pulaski County, who later became editor of the *RPW*. Enlargements in format were made in July 1941 and again in June 1942 (*RPW* 1943m:4). At no charge, copies were even sent to former ROW workers who had been shipped oversees with the military.

The paper was officially closed on August 1, 1943, by an order from the War Department "in the interest of economy, conservation of Ordnance manpower and saving of newsprint and other paper stock" (*RPW* 1943l:2). Hercules Powder Company paid for a final farewell issue on August 13, 1943. It was the opinion of the plant managers that posters and special bulletins distributed round the plant were not nearly as effective as the paper in dissemination of information to the plant workers (HPC [1945]a:425). In May 1944, the Ordnance Department once again authorized publication of plant papers and the *RPW* was revived on June 2, 1944 (HPC [1945]a:440). The end-of-the-war issue was printed on September 28, 1945, but the newspaper continues to inform plant workers today of the goings-on around RAAP.

Billboards and poster boards were erected around the plant to urge safety, participation in bond drives, and attendance contests. Boards erected in different production areas showed the lost-time injury records of each department (*RPW* 1941f:1). The office of the maintenance engineer was topped with a sign "A.B.C. Always Be Careful" as a safety reminder (*RPW* 1942b:1). During the "Keep 'Em Shooting" campaign, the entry gates to the plant were decorated with signs discouraging absenteeism. Some of these signs read, "The War Won't Wait For Those Absent or Late" and "American Production Soldiers Have No Equal, But You Must Be On The Job To Prove It" (*RPW* 1942g:1; *RPW* 1943b:1).

In 1942, the War Production Board was set up to promote closer cooperation between management and labor "with the thought that labor would aid management in obtaining more effective production . . . by . . . [providing] suggestions from the men of the workbench, machine and field" (HPC [1945]a:713). The Suggestion System was established and the Production Promotion Department was developed to implement it (HPC [1945]a:713-715).

The "Keep 'Em Shooting" Production Promotion Program was started at ROW May 1, 1942 (HPC [1945]a:715). Each shift in each production area selected representatives to serve a term of 14 weeks on the Shift Committee (HPC [1945]a:715). The Shift Committee was the first level of review for the suggestions (HPC [1945]a:717). A Line Committee and a Master Committee then reviewed the suggestions (HPC [1945]a:717). When the Master Committee accepted a proposal that it felt was outstanding and worthy of special merit, an Individual Citation Certificate was issued "in recognition of a meritorious contribution to the production of essential materials" (HPC [1945]a:720). This certificate was signed by the President of the Hercules Powder Company (HPC [1945]a:720). An award system was devised through which an employee who had several suggestions accepted received various certificates (HPC [1945]a:720).

The program was taken very seriously. Workers deposited their suggestions with the date, their name, identification number, department, shift, and occupation in one of the 106 Suggestion Boxes scattered throughout the plant (HPC [1945]a:717, 721). Each idea, suggestion, or grievance submitted received a response from the committee. The workers were kept informed as to the suggestions made and whether they were accepted or rejected through a series of bulletin boards and poster boards throughout the plant (HPC [1945]a:719). If the suggestion was not accepted for practice, the person who made the suggestion received a letter from the committee stating the reason why (HPC [1945]a:719). If the person was not satisfied with the decision, he could resubmit his proposal (HPC [1945]a:720). If the suggestion was accepted, the person who made the suggestion received a "Certificate of Acceptance" from the Master Committee (HPC [1945]a:720).

This program proved to be a valuable resource in the production of munitions at the plant. From the initiation of the program on May 1, 1942, through August 1945, 7,262 suggestions were collected with 2,985 accepted, 1,072 rejected, and 713 recommended for investigation. The rest were not recommended to the Master Committee (HPC [1945]a:727). The following are few examples of these outstanding suggestions. Virgil R. Walters of the Smokeless Department suggested that the stick-powder machines used in cutting $^{3}/_{8}$-inch sticks be equipped with three rather than two blade heads for cutting. The efficiency of the Cutting Operation was improved. Lester H. Surratt of the Acid Department suggested that a vacuum device be used to draw acid samples from the Nitric Acid Concentrator, rather than manually drawing the samples. This

device reduced the possibility of acid burns, relieved fume conditions, and reduced maintenance costs. Roy C. Nininger and Clifton D. Warner of the Maintenance Department recommended the installation of a mechanical interlock between the pneumatic door of a sewing machine bay and the sewing machine clutch pedal in the Rolled Powder Area so that the clutch could not be engaged until the pneumatic door was fully closed. This suggestion was an improvement over the electric interlock then in use on No. 3 Rolled Powder and reduced the possibility of fire spreading to other parts of the building (HPC [1945]a:730).

As further incentive, entire plants were recognized and rewarded for their efforts in producing the munitions that supported the armed forces. Factors affecting the Army-Navy "E" Award selection included quantity and quality of product, avoidances of work stoppages, maintenance of fair labor standards, plant safety, sanitation, and effectiveness of management (*RPW* 1945h:1). On September 2, 1942, ROW was presented the Army-Navy "E" flag for excellence in production. ROW was the first of the Hercules-operated plants to receive the award. When the award was presented, a large ceremony was held at the flag raising with Hercules executives, Army officers, and governmental officials in attendance (*RPW* 1942e:1). Only an estimated five percent of the eligible plants won the award during the war, and only five percent of those that won were awarded as many as four stars (Table 12). The Radford plant, however, was exceptional, winning four subsequent awards, each resulting in an additional star to the "E" flag. In 1945, it was decided that the award would be given annually rather than bi-annually. ROW would have received its sixth award in December 1945, but the war brought an end to operations and the program (*RPW* 1945h:1, 2).

Table 12
Army-Navy "E" Awards Presented to Radford Ordnance Works

Awards	Date
1st Award	September 2, 1942
2nd Award	June 19, 1943
3rd Award	December 4, 1943
4th Award	June 26, 1944
5th Award	January 13, 1945

Source: HPC [1945a]:777

Although improvements in technology resulted in increased production, problems were encountered because of the rate of absenteeism in the work force. An editorial in the plant paper, the *Radford Plant Weekly*, in early 1943 stated that "here at ROW we are losing approximately three quarters of a million pounds [of powder production] per month by absenteeism" (*RPW* 1943c:2). One month later plant manager Van Beek stated that the problem was "increasing instead of decreasing" (*RPW* 1943g:3). Therefore, in March 1943, the Production Promotion Department suggested the adoption of a "No Absentee Pledge" program, in which each employee with a six-month perfect attendance record would be issued a Certificate of Attendance signed by his supervisor. Subsequent certificates were to be awarded for 12, 18, 24, 30 or 36, 42, 48 or 54 months of perfect attendance (HPC [1945]a:732). Attendance charts were set up in all operations buildings. In May, a "Plant Absentee Contest" was begun at the plant (HPC [1945]a:732). This program was cause for great competition between the different plant departments since the area attendances were reported in the *Radford Plant Weekly* (1943k:2).

Security

The Plant Protection Department was charged with the responsibility of protecting the plant "from acts of espionage, sabotage, or malicious damage" (HPC [1945]a:449). An investigation team was established which interviewed each applicant and was headed up by a former FBI agent. Investigators were men who had industrial backgrounds. At its peak in July 1945, the department had one supervisor, 26 investigators, four stenographers, and 12 clerks (HPC [1945]a:457). Toward the end of the war when labor was at a premium, field investigators were required to report back within 48 hours on personal information files. The personal information files consisted of pre-employment investigations carried out by the field investigators. The Plant Protection Department kept a filing system containing all personal history reports as well as the fingerprints of each employee for Mason & Hanger and Hercules (HPC [1945]a:453).

An Identification Section was established under the Employment Division of the Personnel and Service Department to set up a card file on all employees, whether they were employed by Hercules, Mason & Hanger, or the Ordnance Department (HPC [1945]a:266). A photographic identification badge, including a payroll number, was issued to each employee at ROW as another means of security (HPC [1945]a:266). This permitted employees to enter only their assigned work area. The use of badges also prevented the entry of unauthorized persons into the plant.

The Plant Protection Department was also responsible for investigation of absenteeism reports for both ROW and NROP. A special investigator was employed to contact employees who had been absent from one week to two to three months "to impress upon the individual absentee the importance of his reporting for work regularly" (HPC [1945]a:458).

After the bombing of Pearl Harbor, security at the plant was stressed. The December 11, 1944 issue of the *Radford Plant Weekly* carried a warning to all employees from Commanding Officer Lieutenant Colonel Serrum stating that they were not to discuss "the layout of the plant, the product manufactured, [or] the status of any construction" with anyone while off the plant site (*RPW* 1941l:1). About one month later, an article appeared in the paper warning against taking powder samples from the plant (*RPW* 1942a:1). This was mainly a concern for the safety of the workers and their families, but no doubt the fear of espionage was also a factor.

The main responsibility of the Guard Force, which was its own department, was to protect the plant property and maintain order at the plant (HPC [1945]a:303). The guards were also responsible for searching employees for matches. Table 13 shows the guard force statistics kept during execution of their duties. Felonious crimes committed off the plant site, such as embezzlement, forgery, and statutory charges were handled by local law enforcement (Table 14; HPC [1945]a:312).

Food Service Facilities

During the early part of the construction phase, Hercules operated five canteens at the plant that sold soft drinks, candy, and snacks. Although these continued in operation throughout the war years, two temporary mess halls were established as well. Mess Hall "A" opened on January 6, 1941, with a seating capacity of 200, serving meals from 7:00 a.m. to 9:00 p.m. (HPC [1945]a:692). This building was located opposite the Mason & Hanger office. Mess Hall "B" opened on January 17, 1941, with a seating capacity of 400 and was located on the hill near the Acid Area. Operation of these facilities was contracted out to Griffin Industries, Inc., of Manchester, North Carolina, on November 1, 1940 (Anonymous n.d.a:Appendix). Hercules provided the equipment for these mess halls and also for the later cafeterias (HPC [1945]a:701).

Table 13
Police Force Statistics at the Radford Ordnance Works

Title or Subject	Period covered	Totals	Remarks
Ammunition expended in pistol range by Police Department	10/1941 to 10/1945	155,375	Rounds
Amount of lost & stolen property recovered	1/1944 to 10/1945	$1052.32	Lost by employees
Arrests	1/1941 to 10/1945	460	
Commercial vehicles searched upon entering the plant	9/1942 to 10/1945	8,599	
Complaints investigated regarding lost or stolen articles	1/1944 to 10/1945	225	
Employees searched for prohibited articles In/Out	8/1941 to 10/1945	1,270,898	Excluding inside spot searches
Employees caught smoking inside plant	8/1941 to 10/1945	432	
Employees found intoxicated in plant and at gate	8/1941 to 10/1945	729	
Employees Infractions of Rules Reports handled	8/1941 to 10/1945	2,660	
Employees caught with matches, lighters, etc.	8/1941 to 10/1945	1,860	At gates and in plant
Investigation of flash fires and accidents	1/1944 to 10/1945	441	
Miles traveled by police motor equipment performing duties	8/1941 to 10/1945	1,792,771	
Plant vehicles searched at gate	1/1944 to 10/1945	63,282	For matches, lighters, tools
Terminated employees escorted from plant	1/1944 to 10/1945	14,533	
Traffic violations reported	8/1941 to 10/1945	565	
Visitor passes issued	10/1941 to 10/1945	6,814	

Source: HPC [1945a]:328

Providing meals at the early construction site was not easy, since water had to be hauled from Radford and the electricity was constantly being cut off. The operator, however, seems to have provided good meals at a reasonable cost. The first menu, reported in the plant newspaper, offered roast prime rib of beef, fresh string beans, mashed potatoes, good coffee, and ice cream for 30 cents, or T-bone steaks and french fries for 60 cents (*RPW* 1940a:1). Breakfasts were equally impressive. For 25 cents a worker could have juice, one egg, two slices of bacon, bread, and coffee, and for 35 cents, two eggs, two slices of bacon or sausage or ham, bread, and coffee (*RPW* 1941a:1).

Two permanent cafeterias were later opened at the plant, one in the barracks area and one in the Administration Area. These opened for business within several months of each other on April 26 and July 24, 1941, respectively, and were also operated by Griffin Industries. The barracks cafeteria seated 400 persons and operated from 7:00 a.m. to 1:00 a.m., seven days a week (HPC [1945]a:692). Mess Hall "A" was converted into the administrative cafeteria and was originally only open for lunch, but was later opened for breakfast and lunch, six days a week (HPC [1945]a:702). An office and food storage building was erected in connection with the cafeterias. By September 1941, the cafeterias were reportedly serving 2,300 meals a day. Potato consumption was 2,000 pounds a week and coffee consumption was 200 pounds a week (*RPW* 1941k:1).

Table 14
Record of Arrests, 1940-1943

Type	Total
Public Drunkenness	196
Speeding and Reckless Driving	74
Driving While Intoxicated	38
Felonious Assault	12
Petty Larceny	10
Assault & Battery	7
Passing Worthless Checks	5
Embezzlement and Forgery	4
Gambling	4
Nonsupport	4
Grand Larceny (Dryer Act)	3
Malicious Trespass	3
Manslaughter	3
Contributing to Delinquency (Statutory)	2
Violation of Parole	2
Arson	1
Concealed Weapons	1
Robbery	1
Total Arrests	370

Source: HPC [1945a]:312

Like the rest of the Allies, the United States was forced to begin rationing certain foodstuffs in 1943. The menus at the plant cafeterias reflected these shortages. Reminding the workers that they were sharing their food supply with American G.I.s abroad, the cafeteria supervisors prepared workers for a change in their eating habits. Such "luxury" items as butter would be scarce; there would also be "less meat, less coffee, less whipped cream and less ice cream and candy." The managers tried to maintain healthy, balanced meals and felt the new eating habits would actually be healthier for the employees (*RPW* 1943f:1).

Economic and Social Effects of the GOCO Plant on the Region and State

The location of the ROW and NROP had a profound effect on the region. It had been a somewhat isolated area with a homogenous population and an agrarian-based economy. The war and the GOCO plants brought people from all over the country and generated a more diversified economy. Many local residents left their farms for production or industrial jobs and did not return to full-time farming after the war. The local traffic jams disappeared after the war but entire new housing developments such as Fairlawn remained. Many of these houses would be purchased by the returning veterans. ROW continued to provide jobs on a reduced scale and, during the Korean and Vietnam wars, employment again increased.

Environmental Legacy

When RAAP was built and first operated during the hectic days of World War II, speed and production were of foremost importance and the impact of such a large undertaking on the environment was not given a great deal of attention. One of the main attractions that brought the Ordnance Department and Hercules to this site was the New River, which provided the water needed to run the plant. Given the number of chemicals used in the production of smokeless powder, there was potential for leakage into the river. Evidence of pollution of the New River by ROW during the war came from a brief article in the *Radford Plant Weekly*. It reported that a man caught a catfish from the river below Strouble's Creek and took it home to fry. It was, however, so impregnated with nitrocotton that it exploded (*RPW* 1941h). In 1947, during the time the plant made ammonium nitrate, there was a substantial fish kill in the river. The Virginia Commission of Game and Inland Fisheries investigated and noted that water samples contained high levels of ammonium nitrate which is highly toxic to fish. It was suspected that the substance entered the river when tank cars hauling the product were washed out and the effluent discharged into the river (Buller 1947).

Agricultural leases for grazing have been available at the New River unit since the deactivation of the installation at the end of the war. Although several hay leases have also been made available at the New River unit, the amount of land devoted to leases has varied over the years (Shorter n.d.:23). A reforestation program was instituted at New River in 1955 to plant trees on all areas where they would not interfere with the unit's mission. The program continued until at least 1968 (Shorter n.d.:18). Today, stands of pine trees cover a large part of the reservation.

The New River itself is the most spectacular natural feature at the Radford plant. It forms a Horseshoe Bend within the plant and there are nearly vertical cliffs along part it. The cliffs are ideal roosting and nesting habitat for buzzards. Currently, black buzzards predominate among the nesting birds, but turkey buzzards can also found here. Of the three large buzzard roosting areas on the east coast, RAAP has the largest population (Terry Thompson, personal communication 1995). The buzzards can also be found roosting on tall structures—notably the water towers near the river area.

Other birds and mammals such as gray squirrels, cottontail rabbits, quail, grouse, and deer are presently found at both the Radford and New River units of the installation. The land is managed in a way that encourages wildlife. One of the current programs is to replace cool season, European grass cover with native vegetation. Native grasses provide more nutrition to wildlife and livestock and require less mowing (Terry Thompson, personal communication 1995). By the 1960s, the overpopulation of deer at both units caused some problems. Beginning in 1966, there was a major program to trap deer and remove them to other areas of the region that lacked a substantial deer population. By 1969, the total number of deer that had been trapped and removed from the installation reached 241 (*The Powder Press* 1969). Later, tranquilizers were used instead of traps. A tightly controlled hunting season is also allowed at the New River unit. Today, many deer herds in southwestern Virginia and West Virginia can be traced to the conservation efforts of RAAP (Terry Thompson, personal communication 1995).

Many of the current environmental policies and pollution abatement procedures that took effect in the 1970s were a result of federal legislation in the 1960s. One of the most notable technical improvements at RAAP was the installation of scrubbers on the power plant stacks. The scrubbers removed the fly ash that habitually covered the ground and workers' cars, and turned the snow gray. The ash removal was cited by one worker as one of the biggest improvements at the plant (Howard Johnson, interview 1995). Currently, the latest technologies are used to treat chemicals and prevent dangerous discharges into the air, land, and water.

The End of World War II

The end of the war on V-J Day, August 13, 1945, brought swift changes to the plant. Major John K. Rouleau, the Commanding Officer, Andrew Van Beek, the Plant Manager, and Captain Van J. Payne, the Police Superintendent, participated in a short program that was broadcast to employees throughout the plant (*RPW* 1945e:1). The program was repeated for each shift.

According to Alene Graham (interview 1995) there were many employees who never returned after that day. Shortly thereafter, hundreds were terminated. There were several small ceremonies held for the last can of powder packed at ROW or the last trench mortar increment manufactured (*RPW* 1945i:8). Contractor personnel dropped from 7,419 on the date of shutdown to 5,423 by September 1. Those production personnel that remained worked a five-day week with only a day shift. The contractor rolls numbered only 875 at the end of 1945, and by February 15, 1946, all personnel had been transferred or terminated with the exception of the office group which handled last minute record keeping (Howell [1951]:7).

On September 4, 1945, Hercules received a contract termination notice from the Field Director of Ammunition Plants. Plans for dealing with the end of the war had already been formulated. In late 1943 and early 1944 Hercules had developed its *Manual for Shutdown Procedure* in anticipation of the eventual termination of operations at ROW. In December 1944 plans were made to deal with any contracts that might be open when the war ended. On August 14, 1945, all open purchase orders were cancelled by telegram, and in the subsequent weeks all commitments were cancelled. Of 1,773 open commitments that existed on V-J Day, Hercules succeeded in canceling 1,365 without further charges (HPC [1945]a:1414). In the production areas, the *Manual for Shutdown Procedure* was followed for each area. All property was inventoried and thoroughly cleaned. A committee from the Ordnance Department and one representative from Hercules made a final inspection. On February 15, 1946, the plant was turned over to the Ordnance Department (Howell [1951]:7).

Orders to terminate activities at the New River Ordnance Plant were also received, dated August 15, 1945, and the plant was declared surplus on August 29, 1945. Following the *Manual for Shutdown Procedure* buildings and equipment at New River were cleaned and inspected, and the buildings were turned over to the Ordnance Department in November 1945 (HPC [1945]b:565).

Many of the former employees of ROW returned to their former homes and jobs while others entered college. Several found employment at VPI&SU, which was expanding as the returning soldiers entered college on the G.I. bill (Alene Graham, interview 1995). Some of the local employees returned to farming or took time off before looking for further work. Many of the women returned to their homes, again to be housewives (*RPW* 1945j:7).

Post-War Years

Between June 1946 and April 1949, the Radford Arsenal was one of 15 wartime explosives plants chosen to produce ammonium nitrate for the War Department's fertilizer production program. The nitric acid area of the plant was reactivated for this production. The fertilizer was shipped to Europe as part of the Marshall Plan (Anonymous [1963]:5). The fertilizer program ended when Hercules was awarded a contract to produce rocket powder in April 1949. Production under this powder contract, however, was small, requiring only 300 employees.

After the Korean conflict began, the pace at the Arsenal quickened. Operations were increased from a 10-shift per week schedule to a 21-shift schedule. The C-Line stick powder and trench mortar facilities were reactivated and it became necessary to reactivate a major part of the plant. During this period, Radford produced single-, double-, and triple-base propellant powders; rolled powder; acid; solvent; nitrocellulose;

and nitroglycerin; and manufactured and loaded cast propellant (Anonymous 1957:15). Component parts for missiles were also produced here by Goodyear Aircraft Corporation (Anonymous 1957:16).

As a part of this build-up the installation was completely refurbished in the first half of the 1950s. Hayes, Seay, Mattern, and Mattern of Roanoke were the engineers for the rehabilitation of the plant, with J.A. Jones Construction Company of Charlotte, North Carolina, as the contractor (MacDonald and Mack 1984:31). All lines, except pentolite and TNT, were rehabilitated and new lines were built for cast propellant and nitroguanidine powders (needed for triple-base powder). This period saw the removal of surplus buildings. Nearly 100 buildings, including the entire pentolite and TNT manufacturing areas, were demolished. The rehabilitation that began in July 1950 was largely completed by the end of 1954.

The Radford Arsenal reached peak production during the Korean conflict in July 1953 when it produced approximately 13 million pounds of powder (Anonymous 1957:16). When hostilities ended in Korea, personnel at the Arsenal declined from a high of 12,057 in December 1952 to a low of 2,268 in 1958. As tensions in Southeast Asia intensified, personnel again increased, however. Employment reached a high of 9,041 in December 1968, but had declined to 4,328 by June 1970 (Anonymous 1970:6).

United States involvement in Southeast Asia resulted in another modernization period at RAAP that began in the 1960s. In 1968 a new TNT plant was built. This was the first facility built in the United States for continuous nitration and purification of TNT (Anonymous 1986), although a TNT plant had been built during the World War II period but never operated (Charles Flynn, interview 1995). RAAP ceased TNT production on July 19, 1986, and the plant was put in stand-by. During Desert Storm, plans were made to reactivate the TNT plant and work was begun, but it was returned to stand-by status before any TNT was produced (Joann Jenkins, Operations Review, RAAP, personal communication 1995).

Also built during the 1970s was a sulfuric acid regenerator, several nitric acid/sulfuric acid concentrators, a continuous nitrocellulose nitration facility, and an ammonia oxidation plant. The Continuous Automated Single-Based Line (CASBL) also was built in the early 1970s and the Continuous Automated Multi-Based Line (CAMBL) was built in the 1980s (MacDonald and Mack 1984:32). These two lines utilized the latest in computer controlled manufacturing technology when they were built but are now considered to be out-of-date (Terry Thompson, personal communication 1995).

There were two major explosions in the 1970s. In May 1974, one line of the TNT plant exploded, damaging the other two lines. Over 100 people were hurt because it occurred at shift change. The most seriously injured worker lost a leg as a result of the explosion. Then in January 1978, the Nitroglycerin Plant 2 exploded leading to the reactivation of Nitroglycerin Area 1 (MacDonald and Mack 1984:32).

During the years subsequent to World War II, a primary focus at Radford has been to produce cast propellant for rockets such as the Honest John, Little John, Nike Atlas, and Nike Hercules rockets (Anonymous 1970:3). One RAAP brochure boasts, "we manufactured the propellant used in every rocket fired by the U.S. forces in the Korean War and the Vietnam Conflict" (Anonymous 1987:2). Today the plant continues to produce double-base, triple-base, and high-energy propellant powder and cast propellant.

SUMMARY AND CONCLUSIONS

The Radford Army Ammunition Plant is composed of what historically was the Radford Ordnance Works and the New River Ordnance Plant. ROW was one of the first facilities constructed as part of the defense build-up in the United States just prior to and during World War II. The ROW was a propellant and explosives plant that was constructed to manufacture smokeless powder and the NROP was a bag loading facility. As originally planned, NROP was to be built adjacent to the ROW manufacturing unit. When the

land was needed to complete ROW, however, NROP was resituated and built about 12 miles away. Until midway through the war, the NROP operated as a separate facility from ROW.

Hercules Powder Company was both the architect-engineer and the contractor-operator for the two facilities. Hercules had World War I experience producing smokeless powder and TNT for the government and in 1940 was one of the few companies with experience in propellants and explosives. Hercules operated six GOCO plants during World War II and has continued to operate RAAP since its inception. Manson & Hanger Company built both facilities: ROW under a subcontract to Hercules and NROP on a direct contract with the government. Mason & Hanger had played an important role in the ordnance build-up throughout World War I and during World War II built four ordnance plants.

ROW played a vital role in the GOCO system during World War II. It was the first plant in production and produced 44 types of propellant. As a pioneering facility, ROW had its own research and development department that developed and tested new products. New workers underwent training at the facility for employment in other ordnance plants, and ROW was the first plant to use women in large numbers in the production lines.

The siting of these industrial, war-related facilities in the Montgomery/Pulaski county region had a dramatic impact on the area. This region of the country is situated in the mountains of southwest Virginia, which at the beginning of World War II was a rural area with an agrarian-based economy. The influx of large numbers of workers both strained and boosted the local economy.

Information regarding the history of the RAAP is quite limited at the installation. The facility maintains an archives but the loss of employees has left several areas without supervision or institutional memory. Although a very good museum is located on the facility, it is not staffed and generally is not open. One of the largest gaps in information was photographic documentation. Only one book of photographs documenting the first months of the construction phase at ROW and NROP was located at the facility. That some World War II-era photographs exist, though, is apparent, since photographs of women production workers at Radford during the war can be found in the published history of Hercules, Inc., by Davis Dyer and David B. Sicilia (1990).

Although drawings and plans of buildings and equipment at RAAP are housed in the Map Room of the Administration Building, due to personnel layoffs, the room is only open for one hour each day. The drawings are indexed but because of the large number of drawings, the indices run to multiple volumes. Most of the plans viewed for this report had a number of changes on them indicating that few "as built" plans survive. The date of revisions to the plans is noted on the plan.

Information on surviving original equipment was difficult to obtain and in-depth research needs to be conducted to determine what original equipment, if any, remains at Radford. Of the present employees, those who have been with the installation the longest began working at RAAP in the 1950s and believe that some of the equipment is original. With the loss of older employees through retirement and death, however, this may not be firsthand information and may not be reliable.

Little information was available on the employment of women in smokeless powder production. Although ROW was one of the first of the GOCO plants to employ women in production, there is little documentation other than articles that appeared in the plant newspaper. Likewise, there is little information on the work of African Americans when the shortage of white males became acute in the latter stages of the war. By 1945 African-American workers operated one entire line at NROP on a three-shift basis, but only a couple of paragraphs were devoted to their contribution in the plant history. Studies that follow the success of women and African Americans in retaining these production positions after the war are lacking.

There were no in-depth studies available on the impact of ROW and NROP on the local communities. A large gap in information is caused by the lack of an archives for the local Radford newspaper, although the Christiansburg and Roanoke newspapers are available on microfilm. An oral history project on Fairlawn by students of Radford University was the best available documentation of its type on defense housing. More research of this type needs to be done quickly since many of the people who lived in the World War II defense housing built as a result of the establishment of ROW are becoming elderly.

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